ARCHIVES OF ACOUSTICS
15, 3–4, 447–463 (1990)

INVESTIGATIONS ON AUDITORY SPACIOUSNESS OF LARGE ACOUSTIC SOURCES WITHIN A ROOM[1]

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This paper presents results of a psychoacoustic experiment which consisted in length estimation of a quasi-linear horizontal sound source, performed by listeners. At preserved similarities of obtained dependences, considerable differences between responses of individual listeners were stated. Size evaluations dit not reflect the source's length, but were in linear dependence with the maximal value of a normalized cross correlation function of signals reaching the listener's left and right ear. An increase of sound level caused an increase of the source's apparent length within the given series of estimations.

Measurement results presented on the background of investigations on sound volume and sound spaciousness in concert halls indicate that volume and auditory spaciousness are different forms of the same impression quantity.

W pracy przedstawiono wyniki eksperymentu psychoakustycznego, w którym słuchacze oceniali długość quasi-liniowego, poziomego źródła dźwięku. Stwierdzono znaczne zróżnicowanie odpowiedzi pomiędzy poszczególnymi słuchaczami przy zachowaniu podobieństwa uzyskanych zależności. Oceny rozległości nie odzwierciedlały długości źródła, natomiast wykazywały liniową zależność od maksymalnej wartości unormowanej funkcji korelacji wzajemnej sygnałów docierających do lewego i prawego ucha słuchacza. Wzrost poziomu dźwięku powodował zwiększenie pozornej długości źródła w ramach danej serii ocen.

Wyniki pomiarów, które przedyskutowano na tle dotychczasowych badań nad wolumenem dźwięku oraz przestrzennością dźwięku w salach koncertowych, wskazują, że wolumen i rozległość słuchowa są różnymi formami tej samej wielkości wrażeniowej.

1. Introduction

A. Auditory spaciousness

Besides sound localization auditory spaciousness is the second feature of sound related with the interpretation of auditory impressions on the background of

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(1) Research was performed within programme CPBP 02.03 and Institute's own studies.

surroundingeus three-dimensional space. Problems of spaciousness have been studied much more rarely than problems of sound localization. This last group of problems has been theoretically founded and descriptive, as well as explanatory, investigations have been carried out (see eg. BLAUERT [5]).

Contemporary knowledge on sound spaciousness perception comes from studies on sound quality in concert halls, mainly. These studies have been performed during the last twenty five years [2, 15, 16]. For the impression of sound spaciousness has been found to be one of the fundamental criteria for sound quality evaluation in concert halls [1, 6, 21].

The problem of sound spaciousness is also found in other fields of psychoacoustics. Changes of impressions of sound spaciousness in binaural fusion investigations are due to differentiation of signals in the left and right ear of the earphones [7]. The impression of spaciousness is a significant factor also in quality estimations of sound transmitted in an electroacoustic system. Thus, many methods of sound transmission have been developed in order to increase the impression of spaciousness (see eg. GARDNER [9]). It is still a live issue [12].

According to the systematics of motions, related to the impression of spaciousness, defined by BLAUERT [6], the conception of the type and size of space formed spontaneously by a listener in a given sound field is called the auditory spatial impression. Two main factors constitute the auditory spatial impression. Namely reverberance and auditory spaciousness. Reverberance, which is related to changes of auditory events in time, is influenced by reverberation and late reflections. Where as, auditory spaciousness is the spatial characteristic of auditory events. It results from early lateral reflections (i.e. delayed not more than about 80 ms with respect to direct sound).

Two physical measures can be found in literature which have been proved to reflect the psychological measure of sound extensity adequately. The ratio energy of early lateral reflections and total sound energy reaching the listener during the first 80 ms is the first measure [2]. While the second one is the absolute maximum value of the interaural cross correlation function of signals reaching both ears, normalized in relation to the total energy of signals [15, 21]. It is sometimes called the degree of coherence [5]. The lower is the degree of coherence of signals, the higher spaciousness is.

The spaciousness estimation depends also on sound level [2]. In Keet's paper a 10 dB increase of sound level caused an increase of angular dimensions of an apparent sound source of 16° [15].

In investigations on sound spaciousness in concert halls auditory spaciousness depends on the particular space and given positions of primary and secondary sound sources [16]. Sometimes spaciousness judgements are expressed in terms of angular measure, as the extension of an apparent sound source [15]. Listeners have the ability of estimating two dimensions of an apparent source – width and depth [6].

B. Sound volume

There is a notion of sound volume in classical psychoacoustics which is one of four attributes of tone (loudness, pitch, volume, density) related to its spaciousness, [22].

Stumpf is considered to be [4, 23] the first one to describe extension (Ausdehnung) as a subjective tone property in 1883. From that time many psychoacoustics have dealed with this aspect of auditory impression which has been called "volume".

It seems characteristic of results of early studies on volume that on one hand its existance as the attribute of tone was not questioned, whereas on the other hand significant differences between estimations of individual listeners were indicated, as well as a strong relation between estimations of volume and loudness [13, 22].

Volume was finally considered an independent attribute of tone when Stevens developed a new research method consisting in volume levelling of two different tones by a listener. THOMAS [23] applied this method in his extensive measurements of equal-volume curves. Thomas, as well as other researchers before him, have stated that tone volume increases with an increase of its intensity and a frequency decrease. These properties of tone volume have been also confirmed by results of investigations on volume scaling with the method of magnitude estimation [18] and the fractionation method [13].

The physiology of hearing explains basic attributes of tone, such as loudness and pitch. A similar explanation was sought for volume. Bekesy, among others, was a suporter of the Lehmann's hypothesis concerning the relation between tone volume and basiliar membrane excitation [4]. Earlier James set forth a hypothesis, in which the ability of sound spaciousness estimation is a learned ability based on the fact that large acoustic sources more frequently produce low frequency and high level sounds, while small sources on the contrary - high frequency and low level sounds. However, results of comparative examinations of the ability of volume estimations of persons with congenial blindness and persons with good sight did not differ and thus did not confirm James's hypothesis [20].

The notion of volume was also applied in estimations of noise spaciousness [24]. It was stated that an increase of noise volume accompanied an increase of sound level, duration and differentiation between signals reaching both ears [20].

As it results from the above discussion volume as a sound attribute was considered in the classical approach separately from spatial features of the sound and its source. Volume assessments were comparative assessments, or they were expressed in arbitrary scale. Only Bekesy from among other authors related volume estimations with space in which the sound source was located and expressed the assessment of an apparent sound source in meters. At the same time he found that the estimation of the source's dimensions does not depend on the width of the sound prodicing loudspeaker [3].

Such two notions as sound volume and auditory spaciousness give rise to the following questions. What mutual relation is there between these psychoacoustic terms? Are these two different quatities, or is there a definite relation between them? Is the size of an apparent sound source a constant value in Euclidean space for given conditions? Is auditory measurement of spaciousness in meters or degrees worth-while? Can the size of a real sound source be estimated directly? Is the estimation of spaciousness equivalent with blurring of sound source localization? A psychoacoustic experiment concerning sound spaciousness estimation was to answer these questions. A sound source with adjustable length was applied in order to determine the influence of dimensions of the source on the estimation of its extension, and to compare spaciousness estimations in conditions characteristic for volume examinations (point source) and spaciousness investigations (horizontally arranged sources).

2. Psychoacoustic experiment

A. Apparatus

A previously developed system for spaciousness examinations of sound produced by a quasi-linear source [10] was used in the experiment.

A system of 30 loudspeakers mounted along the axis of a 300 × 75 cm acoustic baffle was used as a sound source with adjustable length. There was a distance of 7.5 cm between centres of adjacent loudspeakers. Every loudspeaker had its own closed enclosure. Loudspeakers have been chosen from among a greater lot of loudspeakers with respect to the repeatibility of their frequency responses. The three last loudspeakers on one side and four on the other side were dummies. The acoustic baffle was perpendicular to the floor. Loudspeakers were on listener's ear level. A distance of 1.5 m divided the listener from the acoustic baffle. The listener's seat was located symmetrically with respect to the system of the 23 loudspeakers used in the experiment. A pink noise generator with a system of filters on the output was the source of signals.

A band noise with mid-band frequency of 1000 Hz and band width equal to a 1/3 octave and 1/1 octave was used, as well as pink noise with band width limited by the loudspeakers frequency response to the 200–8000 Hz interval. The signal from the generator was transmitted to the system of 23 loudspeaker amplifiers (Fig. 1).

Every loudspeaker could be switched off with an electronic key contained by every amplifier. Keys were microcomputer controlled. Thus, any number of loudspeakers from among the 23 of them could be switched on. In this experiment symmetrical systems of sources, consisting of 1, 3, 5, 9, 15 and 23 loudspeakers, were used.

Double level balancing of sound produced at listening point was applied in the experiment. First of all sound levels were balarced inside the loudspeaker system –

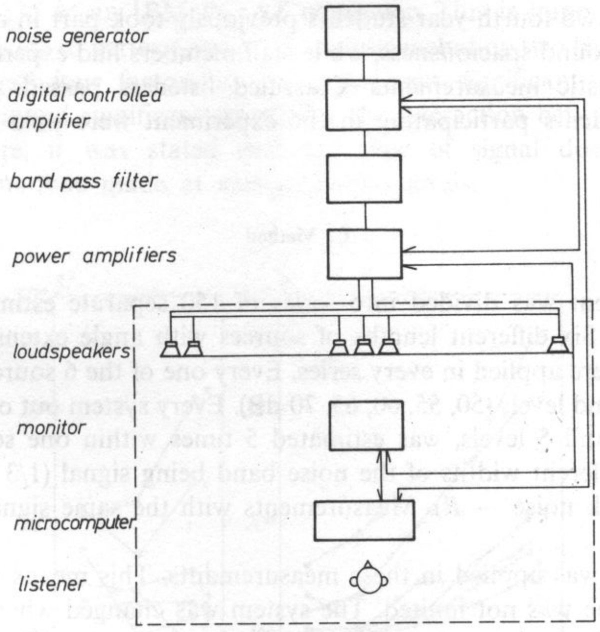

FIG. 1. Block diagram of the measuring system

every loudspeaker in a given system produced a sound with equal level at the listening point. Secondly, systems were balanced – the resultant sound level did not depend on the number of switched on loudspeakers.

Notations on the acoustically transparent fabric covering the loudspeakers were to enable listeners to estimate sound extensity by giving coordinates of boundaries of the apparent sound source. Coordinates could be determined with 1.25 cm accuracy, corresponding to about 0.5° in the central area of the source. Answers of the listener concerning the position of the left and right boundary of the apparent sound source were introduced into a microcomputer from the keyboard. Results of every series of measurements were recorded on a floppy disc.

Monitors within listeners sight, but out of the path of waves travelling from loudspeakers to the observation point, displayed information about takes to be performed by listeners at a given moment.

Measurements were conducted in an audiomonitoring studio with 25 m^2 surface, 92 m^3 volume and reverberation time of about 0.4 s [25].

B. Listeners

6 listeners participated in investigations – students and staff members of the Institute of Telecommunications and Acoustics. Listeners had various previous experience concerning psychoacoustic experiments: two third-year students had no

such experience two fourth-year students previously took part in other experiments concerned with sound spaciousness, while staff members had experiences from many other psycoacoustic measurements. Classified listeners passed audiometric tests successfully. Students participating in the experiment were paid on an hour rate basis.

C. Method

The experiment was divided into series of 150 separate estimations of source extensions each. Six different lengths of sources with angle extension in the range from 3° to 60° were applied in every series. Every one of the 6 sources was presented at 5 different sound levels (50, 55, 60, 65, 70 dB). Every system out of the 30, resulting from 6 sources and 5 levels, was estimated 5 times within one series. Subsequent series applied different widths of the noise band being signal (1/3 octave – *T*, 1/1 octave – *O*, pink noise – *R*). Measurements with the same signal were repeated, also.

Free rhythm was applied in these measuremants. This means that the listening and response time was not limited. The system was changed when the answer was introduced into the microcomputer. The duration of a single series of measurements varied from 20 to 40 minutes for different listeners. The sequence of presentation of sources with different levels and lengths was randomly chosen at the beginning of each series.

3. Results

A. Analysis of collected results

Answers of listeners concerning the position of the left and right boundary of the sound source have been converted into angular values. They form a set of values of the *Y* dependent variable. Every spaciousness estimation *Y*, was obtained for a definite combination of independent variables. The angle extension of the sound source (variable *P*6) and sound level produced by the source (variable *P*5) were the independent variables. They were randomized within one measurement series. Furthermore, there were two independent variables which were the parameters of a given series. These were: listeners number (variable *P*2) and symbol of noise bands (variable *P*4).

For such a great number of factors in the experiment it becomes a problem to present the effect of individual independent variables on the result of measurements and interactions between variables. These problems were solved by using the ANOVA analysis of variance [8] in statistic elaborations of results. However, a four-factor analysis of variance, including all possible interactions, requires over

1100 KByte of RAM in an IBM PC AT computer. This is impossible to achieve. However, it is possible to perform variance analysis including two factor interactions. ANOVA proved all four factors of the experiment significant. Also two-factor interactions were found significant, except for the interaction between variables $P4$ and $P5$. Therefore, it was stated that the type of signal does not influence spaciousness estimations made at various sound levels.

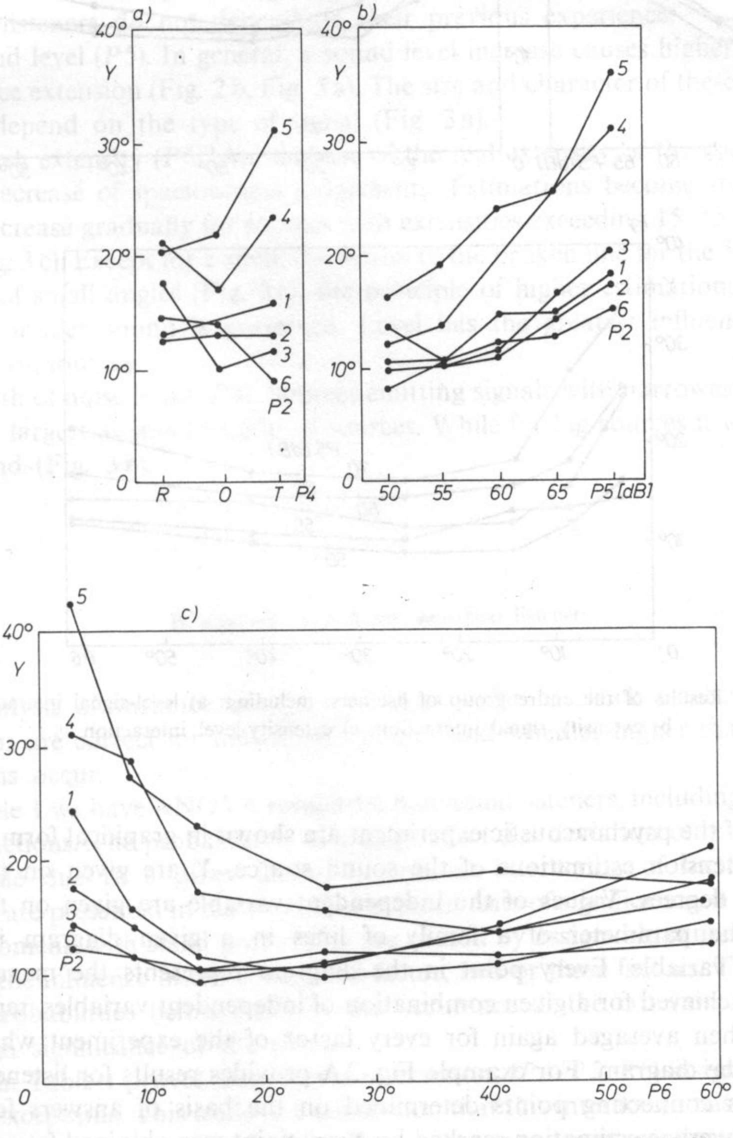

FIG. 2. Measurement results for individual listeners in terms of: a) type of signal $P4$, b) sound level $P5$, c) extensity of the sound source $P6$

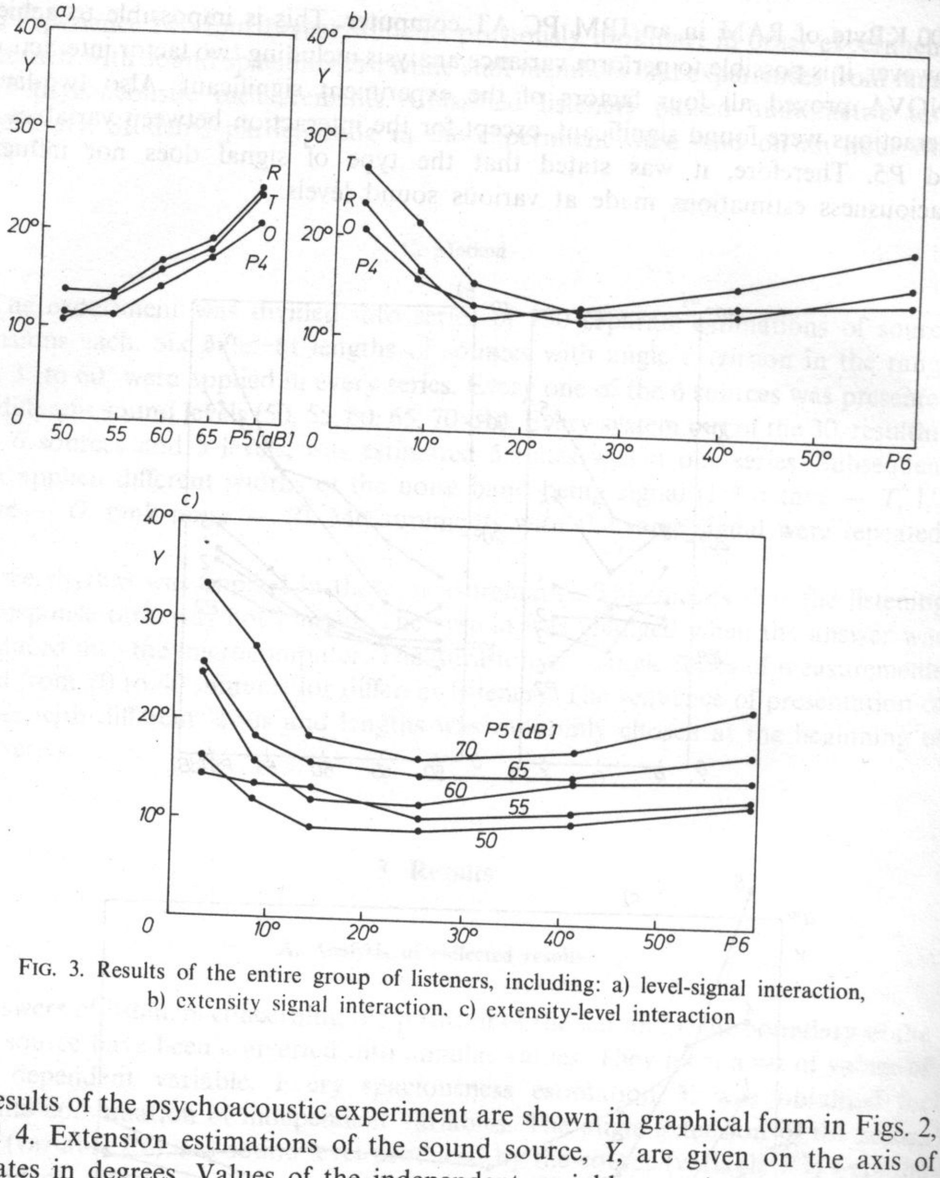

FIG. 3. Results of the entire group of listeners, including: a) level-signal interaction, b) extensity signal interaction, c) extensity-level interaction

Results of the psychoacoustic experiment are shown in graphical form in Figs. 2, 3 and 4. Extension estimations of the sound source, Y, are given on the axis of ordinates in degrees. Values of the independent variable are given on the axis of abscissae. The parameter of a family of lines in a given diagram is another independent variable. Every point in the diagram represents the mean value of estimations achieved for a given combination of independent variables, repeated five times, and then averaged again for every factor of the experiment which is not included in the diagram. For example Fig. 2A provides results for listener 4 in the form of lines connecting points determined on the basis of answers for various signals. The average estimation marked by every point was obtained from five times repeated spaciousness estmations made for six differrent lengths of the source. Then, every one out of these thirty combinations had to be included for every one out of five values of sound level. Therefore, it is an average of 150 answers.

The effect of individual factors on estimations can be described on the basis of data from Figs 2 and 3:

1. Listeners (*P*2). In spite of differences in absolute values of estimations between individual listeners, the arrangement of estimations was similar with respect to source extensity (Fig. 2 c), as well as sound level (Fig. 2 b). No regularity was noticed for lines for different signals (Fig. 2 a). Differences between estimations made by individual listeners do not depend on their previous experience.

2. Sound level (*P*5). In general, a sound level increase causes higher judgements of the source extension (Fig. 2 b, Fig. 3 a). The size and character of these judgements does not depend on the type of signal (Fig. 3 a).

3. Source extensity (*P*6). An increase of the real extensity of the source initially causes a decrease of spaciousness judgements. Estimations become stable or even begin to increase gradually for sources with extensities exceeding 15° to 20° (Fig. 2 c, Fig. 3 b Fig. 3 c). Except for a small distortion of the broken line for the 55 dB level in the range of small angles (Fig. 3 c), the principle of higher estimations for sources generating louder sound is preserved. Level has the greatest influence for small extensities of sources.

4. Width of noise band (*P*4). Sources emitting signals with narrowest bands were considered largest at small lengths of sources. While for big sources it was the other way around (Fig. 3 b).

B. Analysis of data for individual listeners

An analysis of variance was performed in order to check whether the above conclusions are correct for individual listeners and whether higher than two-factor interactions occur.

In Table 1 we have ANOVA results for individual listeners, including main effects and interactions. The probabilities of a given effect (i.e. deviation of results from the mean value due to a given factor, or mutual interaction of factors) occuring randomly are presented in table's columns. As in tests of significance, it was accepted that phenomena with small probability are caused by assignable causes. In our case these are the influence of the considered factor, two or three factors. The zero value denotes probabilities below 0.001 of the occurance of the criterion variable, and hence high significance of the effect.

Data in Table 1 proves three-factor interactions (*P*4–*P*5–*P*6) insignificant for all listeners, except one. This leads to a conclusion that this interaction has no regularity and further analysis can be limited to effects of lower order interactions, illustrated in Fig. 4. This figure presents spaciousness estimations of a sound source made by every

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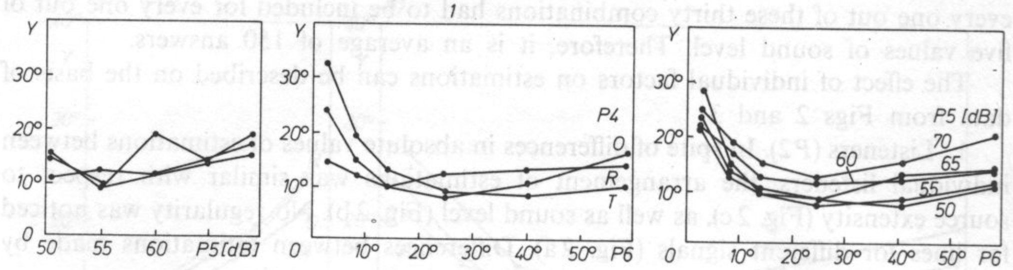
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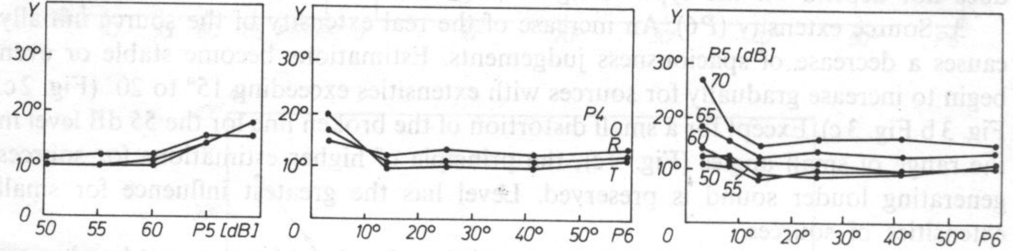
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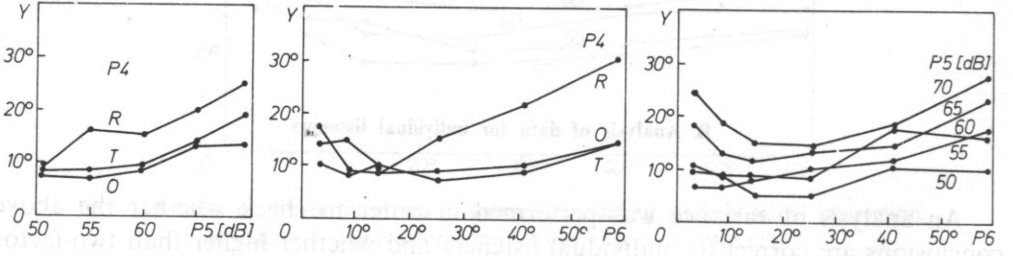
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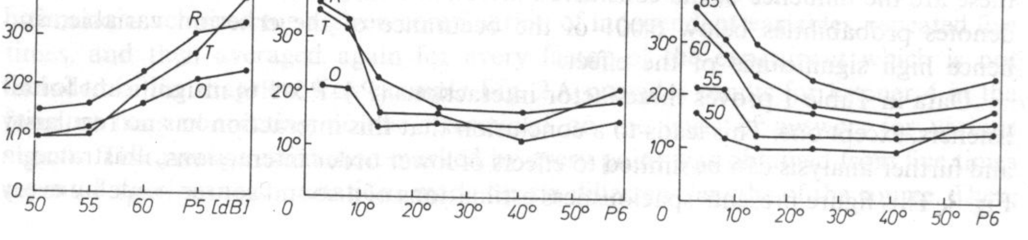
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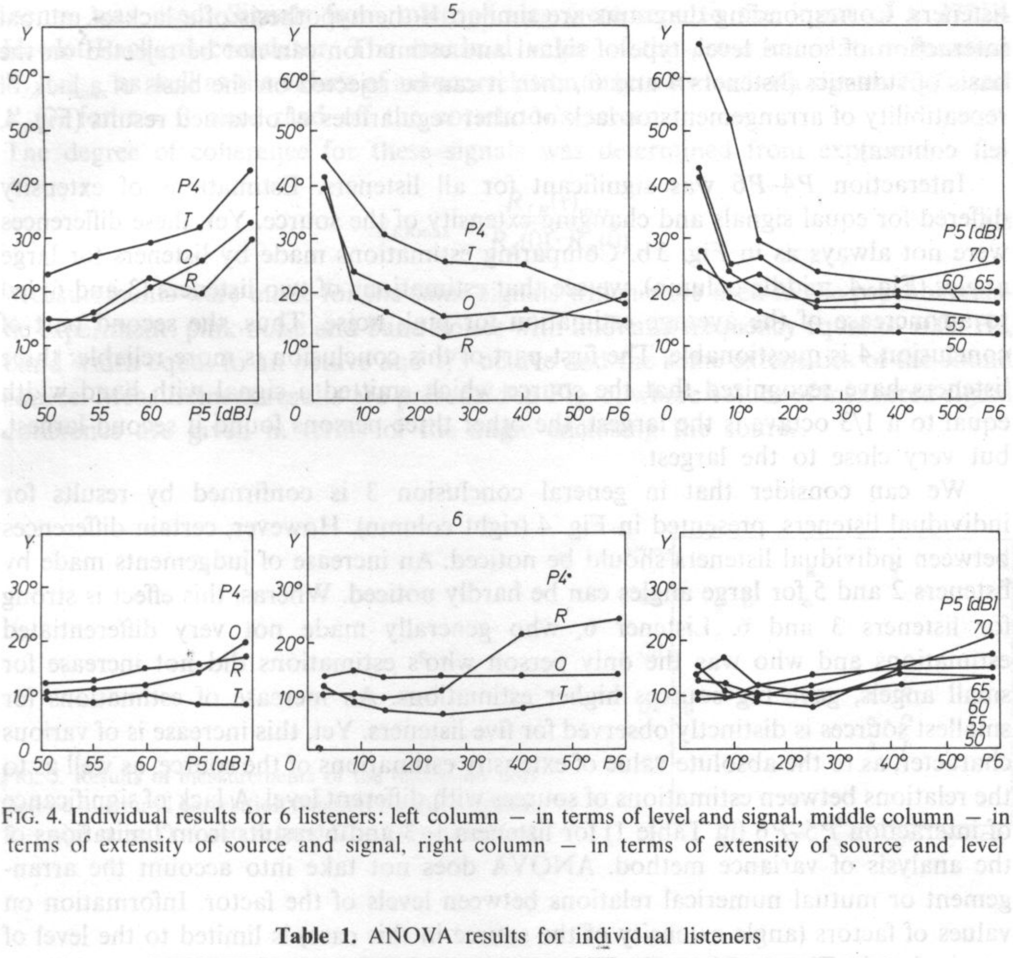

FIG. 4. Individual results for 6 listeners: left column – in terms of level and signal, middle column – in terms of extensity of source and signal, right column – in terms of extensity of source and level

Table 1. ANOVA results for individual listeners

	Listener effect/interaction						
nr	P4	P5	P6	P4-P5	P4-P6	P5-P6	P4-P5-P6
1	0,002	0	0	0,760	0	0,834	0,31
2	0,704	0	0	0,116	0	0	0,232
3	0	0	0	0,082	0	0,452	0,589
4	0	0	0	0	0	0	0,558
5	0	0	0	0,607	0	0	0
6	0	0	0	0	0	0,533	0,037

listener separately, in terms of sound level (left column) and extensity of the source (middle and right column). The type of signal (left and middle column) and sound level (right column) are parameters of families of lines in diagrams.

Conclusions made previously find a confirmation in data for individual listeners. The influence of the $P4$–$P5$ interaction is statistically insignificant for a majority of listeners. Corresponding diagrams are similar. If the hypothesis of a lack of mutual interaction of sound level, type of signal and estimation can not be rejected on the basis of statistics (listeners 4 and 6), then it can be rejected on the basis of a lack of repeatibility of arrangements or lack of other regularities of obtained results (Fig. 4, left column).

Interaction $P4$–$P6$ was significant for all listeners. Estimations of extensity differed for equal signals and changing extensity of the source. Yet, these differences were not always as in Fig. 3 b. Comparing estimations made by listeners for large angles (Fig. 4, middle column), we see that estimations of two listeners (3 and 6) led to an increase of the average estimation for pink noise. Thus, the second part of conclusion 4 is questionable. The first part of this conclusion is more reliable: three listeners have recognized that the source which emitted a signal with band width equal to a 1/3 octave is the largest, the other three persons found it second largest, but very close to the largest.

We can consider that in general conclusion 3 is confirmed by results for individual listeners, presented in Fig. 4 (right column). However, certain differences between individual listeners should be noticed. An increase of judgements made by listeners 2 and 5 for large angles can be hardly noticed. Wheras, this effect is strong for listeners 3 and 6. Listener 6, who generally made not very differentiated estimations and who was the only person who's estimations did not increase for small angels, gave big sources higher estimations. An increase of estimations for smallest sources is distinctly observed for five listeners. Yet, this increase is of various character, as to the absolute value of extensity estimations of the source, as well as to the relations between estimations of sources with different level. A lack of significance of interaction $P5$–$P6$ (in Table 1) for listeners 1, 3 and 6 results from limitations of the analysis of variance method. ANOVA does not take into account the arrangement or mutual numerical relations between levels of the factor. Information on values of factors (angle extensity of the source in this case) is limited to the level of nominal scale. The stated regularity becomes visible when results are presented in the form of a diagram, in terms of angle, measured in ratio scale.

4. Measurements of the coefficient of interaural correlation

Practically a lack of a relation of extensity evaluations with actual dimensions of the sound source, or even the occurrence of reverse estimations for small sources is the most distinct characteristic of obtained results. In order to explain this effect, the value of the parameter related with the evaluation of sound spaciousness in concert halls was measured. The absolute value of the maximum interaural cross correlation function of signals reaching both ears of the listener, related to the total energy of these signals, is this parameter. A pair of microphones, 18 cm from each other and placed in the spot where the listener's head was during psychoacoustic measure-

ments, was used. Signals from microphones were sent to the input of a 3721A Hewlet-Packard correlator. The maximal value of the cross correlation function $R_{LR}(\tau)_{\max}$ as well as the values of autocorrelation functions for both signals $R_L(0)$ and $R_R(0)$ for $\tau = 0$ were read off the correlator's screen.
The degree of coherence for these signals was determined from expression:

$$\varrho_{LR\max} = \frac{R_{LR}(\tau)_{\max}}{R_L(0) \cdot R_R(0)}. \tag{1}$$

Measurements were made for the same signals which were used in the psychoacoustic experiment: pink noise and band noises with midband frequency equal to 1000 Hz, band width equal to an octave and 1/3 octave and the same extensities of the sound source. Measurement results are presented in Fig. 5, where values of measured signal coherence are given in terms of the angle enclosing the source.

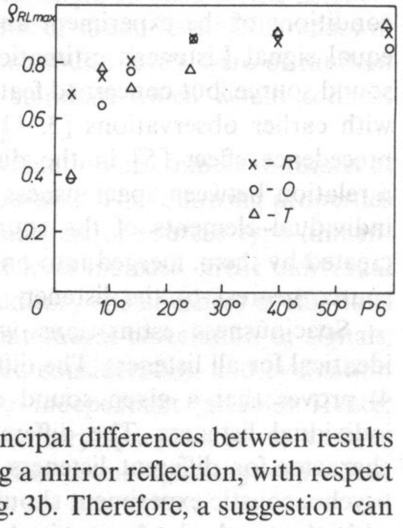

FIG. 5. Results of measurements of the maximum normalized interaural correlation function for three signals: R – pink noise, O – octave band, T – 1/3 octave band

We can see from the Figure that there are no principal differences between results for various signals. All results lie on a line resembling a mirror reflection, with respect to a line parallel to the x– axis, of lines shown in Fig. 3b. Therefore, a suggestion can be made that there is a simple dependence between the maximum value of the normalized function of interaural correlation and the estimation of the sound source extension Figures 3b and 5 are parametric diagrams of this dependence. Just like Keet [5], we have assumed a linear dependence between $(1-\varrho_{LR\max})$ and the estimation of the source's width Y in the following form

$$Y = k \cdot (1 - \varrho_{LR\max}) + Y_o, \tag{2}$$

where k is the slope of a straight line, Y_o is the minimal value of estimation for identical signals in both ears. Values of coefficients k and Y_o were determined by means of the least square method and introduced to expression (2), giving

$$Y = 30.5 - 18.75\varrho_{RL\max}. \tag{3}$$

For k on the 0.95 significance level, the confidence interval is equal to $2 \cdot 1.75$. The value of the coefficient of correlation r was calculated in order to check the power of the relation between $(1-\varrho_{RL\max})$ and Y. It was equal to 0.67.

From equation (3) we can see that estimations of sources extension vary in a range from 11.75° for fully coherent signals to 30.5° for non-correlated signals. However, it should be noticed that this is data averaged for a definite group of listeners, who gave very differentiated estimations of spaciousness, but had a common general trend. A comparison between lines presented in Figs. 3b and 5 leads to a suggestion that there is still another factor, apart from coherence of signals, which influenced spaciousness estimations. This is indicated also by a distinct increase of estimations for the largest sources.

5. Discussion and conclusions

With reference to questions formulated in the introduction we can state that listeners could not determine the position of the actual limits of a sound source in conditions of the experiment and with all elements of the source supplied with an equal signal Listener's estimations did not concern physical characteristics of the sound source, but concerned features of the impression. This conclusion is consistent with earlier observations [3, 11, 19]. The effect of summing localization and the precedence effect [5] in the discussed experiment are the reasons for a lack of a relation between spaciousness estimations and length of the source. Signals from individual elements of the source were so similar that the auditory impression, created by them, merged into one image located in the middle of a symmetric sound source nearest to the listener.

Spaciousness estimations were made according to an imposed ratio scale identical for all listeners. The differentiation of individual estimations (see Fig. 2 and 4) proves that a given sound created a different impression of spaciousness for individual listeners. The differentiation of values of estimations at their similar character for different listeners at the same time leads to a conclusion that this psychoacoustic experiment should be interpreted as scaling of auditory spaciousness with the method of magnitude estimation. Here we have an analogy to other psychoacoustic experiments aimed at the investigation of dependendes between the quantitative attribute of impression and physical quantities, such as for loudness scaling [18].

A comparison of results of the experiment with listeners, with results of measurements of the correlation function proves that the statistic similarity of signals reaching the listener's ears and expressed by the maximum of a normalized cross-correlation function was decisive to spaciousness evaluations. From the linear dependence between Y and $\varrho_{RL\max}$, expressed by equation (3), we can see that when the correlation coefficient is changed by 0.1 then the evaluation of the sound source's width changes by about 1.9° on the average. This change was equal to 3.8° for sounds with 70 dB level. It is similar to the value of 5.4° achieved by Keet for the 73 dB (A) level [15].

Sound level was the second important factor which influenced evaluations. A linear model of evaluation changes due to extensity in terms of sound level was accepted. In order to compare our results with results of other authors, the average and greatest slopes were calculated. They were equal to 0.55°/dB and 0.93°/dB for a single loudspeaker source ($\varrho_{RL\max} = 0.5$) respectively. As it was mentioned before, Keet obtained a slope of 1.6°/dB. However, a power function analogic to that accepted by Stevens for loudness [22] between spaciousness evaluations and acoustic pressure seems more suitable here. Calculated values of the exponent varied from 0.18 for a signal from a single loudspeaker source to about 0.13 for sources radiating signals with degree of coherence equal to about 0.9

In order to fully determine the relation between spaciousness evaluations and level, we should notice that within one series of measurements sound level was changed, as well as extensity of the source. In experiments previously conducted by the authors [11] sound level within one series was constant. In such a case listeners did not relate spaciousness evaluations with the value of sound level. Differences in evaluations between individual series, i.e. for different sound levels were of random character and proved that there was no constant standard which would connect sound level with estimations of spaciousness [11].

Presented properties of sound source extensity evaluation are similar to results of investigations on sound volume and auditory spaciousness. The following properties are characteristic of volume: independence of evaluations of sources type (dimensions), increase of evaluations accompanying sound level increase, great individual variability of evaluations. Then, the similarity to auditory spaciousness evaluations consists in: the dependence of evaluations on the interaural correlation of signals, proportionality between evaluations and sound level, consideration and evaluation of width changes of the apparent sound source due to independent variables. Hence, it seems that we can consider volume as well as auditory spaciousness as various forms of the same impression quantity. It is a multidimensional quantity, dependent on an entire set of physical factors.

The stated lack of dependence between dimensions of the source and extension evaluations is in conflict with James'es hypothesis, presented in the introduction and concerned with the practical foundation of volumen's properties consisting in the evaluation of the sound source's size.

In order to explain the mechanism of forming an impression of spaciousness, on the basis of stated dependence on interaural correlation, a binaural correlation model of signal processing has to be applied (e.g. [17]). Because of the dependence of evaluations on sound level, the model has to include the intensity of the stimulus, may be in relation with the excitation surface of the basiliar membrane. The necessity of assuring the functioning of the model for monaural hearing results from the existance of such an ability of man [20].

6. Summary and final remarks

Performed research has led to the determination of characteristics of sound volume as well as auditory spaciousness in listener's evaluations.

Two factors, i.e. sound level and degree of coherence influenced evaluations. The first factor is rather associated with volume, while the second one – with the width of an apparent sound source. Geometric dimensions of the actual sound source did not influence evaluations.

A dependence between evaluations and width of noise band was not stated. This conclusion can not be considered as final, because the construction of the psychoacoustic experiment makes it impossible to compare directly sounds with different bands. As it can be seen from an analogic situation concerning investigations on the influence of sound level, experiments including spaciousness evaluations are very sensitive to possibilities of direct comparison between examined factors. This results from a lack of a constant standard relating the value of the estimation and parameters of the signal.

The problem of a relation between auditory spaciousness and localization blurring still remains among questions whithout satisfactory answers. Data from literature indicate that an increase of localization blurring accompanies an increase of the impression of spaciousness [14]. However, this is far from complete knowledge. In the conditons of our experiment applying a symmetric source we could not achieve data concerning localization.

Also the cause for a discrepancy between listeners' evaluations and the maximum of interaural correlation function for longest sources remains unexplained. Further research should be aimed at the determination whether it is the effect of a not identified physical factor, or maybe this discrepancy could be reduced by applying a different technique of measuring the correlation function.

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Received on June 11, 1989