

Proceedings of The Institute of Acoustics

THE SUBJECTIVE RESPONSE TO EARLY REFLECTIONS IN AUDITORIA

E COLLADOS

UNIVERSITY COLLEGE LONDON

INTRODUCTION

A programme is currently under way in order to investigate the effects of early reflections in music auditoria as a component of the auditory impression. The programme involves subjective tests conducted in an actual concert hall using artificial music sources. The convenience of performing tests in these conditions is based on the assumption that (a) complex reflections patterns cannot be fully simulated with the available facilities and (b) the visual environment is a significant component of the response. It is essential, however, to carry out a number of preliminary tests under laboratory conditions in order to develop the testing method. This paper describes the series of laboratory tests and some of their results.

The physical variables are kept to a minimum so as to provide the basic components of the sound field. The results, consequently, are restricted by the experimental conditions and they are expected to reveal trends in the measured variables rather than absolute values.

Two problems were found particularly relevant during pilot tests. Firstly, the lack of a simple description of the impression perceived and, secondly, the considerable sensitivity of the results to the presentation method. The investigation, therefore, aims to the following objectives:

- i) a qualitative description of the impressions experienced
- ii) the measurement of the subjective sensitivity to stimuli variations
- iii) the elaboration of a reliable presentation procedure

EXPERIMENTAL SET-UP

All tests were performed in a small anechoic chamber (20 m³) with an array of five loudspeakers. (See Table 1). As the size of the chamber prevented a surrounding array to simulate the diffuse components, a single loudspeaker above the listener's head was used to provide the reverberation signal. A tendency to localise this source behind the subject was avoided by adding a second frontal loudspeaker, fed with the same signal, with the balance adjusted for maximum subjective diffuseness.

SIGNAL	DELAY (ms)	ENERGY (% of total)	SOURCE	AZIMUTH (deg)	ELEVATION (deg)
Dry	0	up to 25	1 Frontal	0	-10
Dry	23, 47	up to 12	2 Lateral right	+60	-5
Dry	37, 55	up to 20	3 Lateral left	-60	-5
Dry	29	5	4 Overhead	0	+90
Reverberation mixed	20	15	5 Lower front	0	-30
Reverberation	75	50			

Table 1. Components of the synthetic sound field.

Proceedings of The Institute of Acoustics

THE SUBJECTIVE RESPONSE TO EARLY REFLECTIONS IN AUDITORIA.

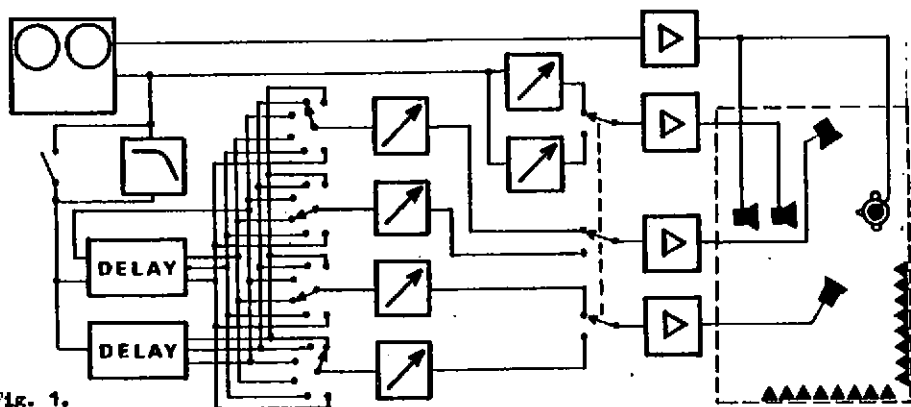


Fig. 1.

The dry signal was obtained from the mixed left and right channels of the ERS Anechoic Music tape. The reverberant signal was taken from a reverberation room adjusted to 1.5 s EDT at 1 kHz, delayed 75 ms. It was decided later to add some non-lateral early energy consisting of an overhead reflection and attenuated reverberation delayed 20 ms.

TEST DESIGN

In the comparison tests the samples were presented consecutively instead of the usual instant switching between samples. The total energy was kept constant during each presentation. The samples were selected through pilot tests, having a homogeneous content and level, a duration of about 15 s and separated by a 2 s pause. Each stimulus was a pair of samples consisting of the same music excerpt with low and high level of lateral reflections respectively.

Initial experiments showed that it was difficult for untrained subjects to compare stimuli with no indication of the attribute to be considered. In order to avoid biasing the response by proposing a particular attribute, a list was provided and the task was to assess variations in each attribute after comparing the samples. This test allowed the listeners to train themselves and to become acquainted with the variety of experiences to be expected. A second purpose of this test was to find terms for describing the subjective effects that were normally shared and used by ordinary listeners.

Another test was designed to measure the differential sensitivity of subjects by applying the constant stimulus method. A standard sample was followed by a variable one and these pairs of samples were presented twice in random order. As subjects felt reluctant to make categorical judgements (identical-different), they were asked to estimate the noticeability of any difference on a triple choice scale: easily noticeable, barely noticeable and not noticeable.

The last test is based on the impression of broadening of the source and uses the parameter suggested by Keet [1]: Apparent Source Width (ASW). A single passage of music lasting 23 s was presented. A reference scale was displayed showing steps every 15 degrees and the subject was requested to assess the ASW.

Proceedings of The Institute of Acoustics

THE SUBJECTIVE RESPONSE TO EARLY REFLECTIONS IN AUDITORIA

The samples were presented at two average levels: 73 dBA and 78 dBA. The ratio lateral to direct energy E_{ld} was varied from -9.5 to +6 dB. The number of lateral reflections was usually 4 but a reduced range of samples included 2 and 6 reflections delayed 23 to 70 ms. Some samples were also filtered with a low pass, 2 kHz, 12 dB/oct filter. The presentation order was varied for each subject to compensate for time effects.

RESULTS AND DISCUSSION

The results presented consider over 500 judgements made by 12 subjects of age 20 to 35. Results of the first test are shown in fig. 2. The rating categories were given arbitrary values from -3 to +3. Normalization of the scale was not attempted, so the results are regarded as indicative only. There is agreement that the most noticeable changes involve the attributes of room size, width, envelopment and spaciousness.

Results of the second test are shown in fig. 3. The differential limen measured is 2.1 dB increase in the ratio lateral to direct energy. This value is higher than that measured by Reichardt and Schmidt [2] as was expected due to the lower resolution of the method used. The reliability was rather low with only 76% of the subjects reporting the same judgement in the second presentation. The variation of the error was investigated and was found to be independent of the stimuli. The error is therefore not due to stimuli confusion but to a random cause, possibly a momentary loss of concentration. An additional judgement of confidence with each assessment would be useful in further tests.

The ASW results against E_{ld} show a roughly linear variation above a certain threshold. (See fig. 4). For a level of 73 dBA the threshold is $E_{ld} = -6.8$ dB and the slope is 5.6 deg/dB. For a level of 78 dBA the threshold is $E_{ld} = -8.1$ dB and the slope is 6.1 deg/dB. The average difference in ASW for a 5 dB increase in level is 12 dB, but has low statistical significance. This value is comparable to that found by Keet [1] but substantially lower than that reported by Conant [3]

Finally, an unexpected result was a consistent variation in ASW when the number of reflections was reduced to only two, keeping their total energy constant. A masking effect of the overhead reflection was suspected and different delays were tried with similar results. This variation is in conflict with the usual assumption of energy integration and with results by Lochner and Burger [4] and Barron [5]. More accurate and definite results are expected to be obtained from the full scale study.

- REFERENCES: [1] W de V KEET 1968 6th ICA, Tokio, paper E-2-4
[2] W REICHARDT and W SCHMIDT 1967 Acustica 18, 274
[3] D A CONANT 1976 91st ASA Meeting, paper E-4
[4] J P A LOCHNER and J F BURGER 1958 Acustica 8, 1
[5] M BARRON 1971 J Sound Vib. 15, 475

ACKNOWLEDGEMENTS

This work was partially supported by the Central Research Fund, University of London.

Proceedings of The Institute of Acoustics

THE SUBJECTIVE RESPONSE TO EARLY REFLECTIONS IN AUDITORIA

CLARITY CL
DEPTH DE
WARMTH WA
ENVELOPMENT EN
LOUDNESS LO
PROXIMITY PR
LIVENESS LI
AMBLENCE AM
WIDTH WI
BRILLIANCE BR
ROOM SIZE RS
REVERBERANCE RE
SPACIOUSNESS SP
OVERALL QUALITY OQ

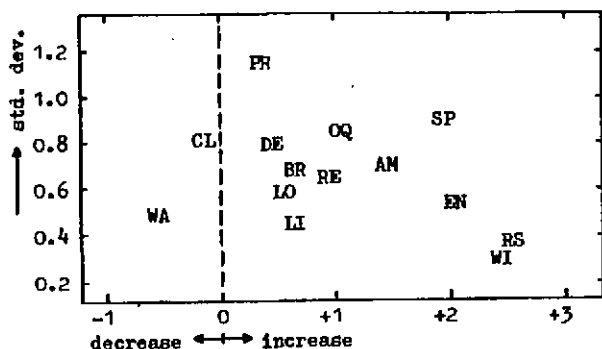


Fig. 2. Mean and standard deviation of the variation in the attributes after comparison of two samples with lateral/direct energy ratio -6 dB and +2 dB. Variation scale: 0, no variation; 1 slight; 2, moderate; 3, substantial.

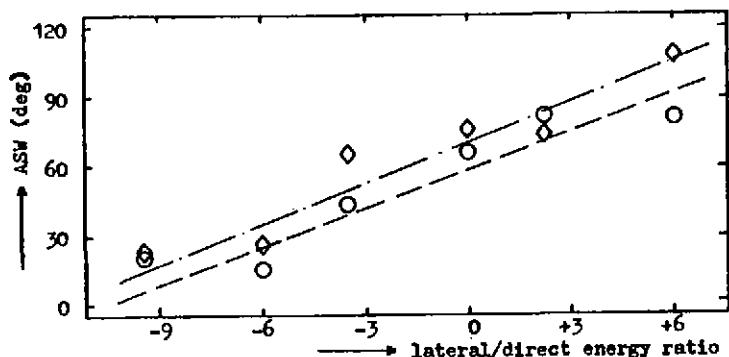


Fig. 3. Average Apparent Source Width against lateral/direct energy ratio. Level: (O), 73 dBA; (◊), 78 dBA. Values for $E_{ld} = -9.5$ not included in the regression shown. (---), 73 dBA; (—), 78 dBA.

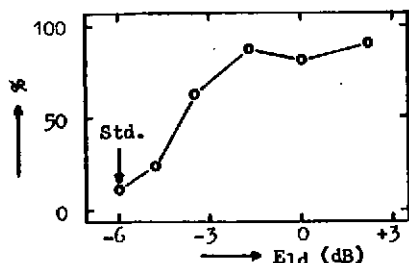


Fig. 4. Percentage of 'different' judgements for several ratios E_{ld} . Standard $E_{ld} = -6$ dB. Level: +73 dBA.

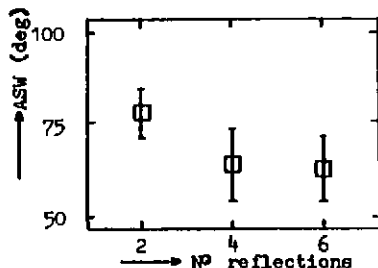


Fig. 5. ASW for different number of reflections at constant level: 73 dBA. $E_{ld} = 0$ dB.