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SUBJECTIVE ASSESSMENT OF CONCERT HALL ACOUSTICS

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INTRODUCTION

A study was recently carried out to identify relationships between physical room acoustic parameters (developed by various authors based on laboratory experiments) and subjective acoustic experiences, which takes into account environmental complexity in the real acoustic conditions of concert halls. The study was conducted at live concerts in two concert halls with the aim first to identify acoustic experiences, and secondly to test whether or not these could be explained by the selected physical room acoustic parameters. This paper describes the subjective evaluation tests used for the identification of acoustic experiences and some of their results.

EXPERIMENTAL PROCEDURE

A previous study to justify experimentally a number of labels describing acoustic qualities of concert halls was reported by Wilkens (3) who used German labels and failed to include aspects of sound such as spatial impression. To the present authors' knowledge no study aimed at systematically selecting labels in English has been reported in the literature. In view of this the subjective evaluation experiments of this study were carried out in three stages. The first stage was concerned with the development of a number of opposite labels describing the acoustic qualities of concert halls. Eighty-six labels were compiled from a thesaurus and from relevant acoustic literature (1, 4). These labels were independently sorted into pairs of antonyms by thirty concert-goers. The fifty-four resulting adjectival pairs were then used as the poles of bipolar rating scales in the next stage.

The second experiment, in which sixty-one assessors listened to recorded music, was designed to reduce the number of these rating scales to a small no. of independent sets (factors). The music consisted of passages from the classical and romantic repertoire selected from commercial recordings. The raw judgments were analysed by factor analysis which produced five independent factors, namely BODY, CLARITY, TONAL QUALITY, EXTENT and PROXIMITY. The results are shown in Table 1. In order to represent these five factors twenty-seven scales were evolved which in turn were used in a series of subjective evaluations at three public concerts.

The evaluations made at these concerts formed the third stage of the experiments and were used to test the validity of the five factors under real concert hall conditions. The first two concerts (A and B) took place in the Fairfield Hall Croydon, and the third concert (C) in the Queen Elizabeth Hall London. One group of twenty-eight assessors was used in each of the three concerts while fifty-two additional assessors were used in concert A. In these concerts the music programmes were also primarily from the classical and romantic repertoire. Four to five independent factors were produced from factor

analysis of the raw judgments. Results from concert A are shown in Table 2. The factors BODY, CLARITY, TONAL QUALITY and PROXIMITY were re-extracted in each of the three concerts. The factors SPACIOUSNESS and INTIMACY which had not been produced in the recorded music test emerged from the evaluations of concerts A and B respectively.

DISCUSSION

These results show that the terms used by concert-goers to describe concert hall acoustics refer to a much smaller number of independent sets of ratings or factors. This was also one of the findings of Hawkes (2) and Wilkens (3). The stability of four of these factors in the recorded music evaluation and each of the three live concerts has demonstrated that there are common subjective features between the two types of sound field. It will be noted that some scales appear on more than one independent factor. This shows that subjects differed in their understanding of the sound aspect to which the scale refers. For example, the scale "spacious" appeared together with the scale "reverberant" on factor BODY and also appeared independently on other factors (see Table 1). This explains why, although "spacious" and "reverberant" are usually used by acousticians (Barron (5)) to describe distinct subjective effects, Eysholdt et al (4) found that the two semantic descriptions were not subjectively distinguishable.

The results show that the responses described by the labels "full bodied", "voluminous", "resonant" etc. which appeared on factor BODY, are collectively independent of CLARITY, contrary to the view that these form the opposite pole of subjective clarity on one psychological continuum.

In order to investigate whether the interposition variation of subjective data was produced by some systematic objective influence, or whether it was merely the effect of variation between subjects, an analysis of variance test was applied to the subjective factor scores for each factor. Results are shown in Table 3 and demonstrate that for almost all factors the subjective judgments were affected by some systematic objective influence. The identification of these will be the subject of future publications.

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TABLE 1 : ROTATED FACTOR MATRIX ; RECORDED MUSIC EVALUATION

No.	RATING SCALES (-)	RATING SCALES (+)	FACTOR 1 BODY	FACTOR 2 CLARITY	FACTOR 3 TONAL QUALITY	FACTOR 4 EXTENT	FACTOR 5 PROXIMITY
1	UNENJOYABLE	- ENJOYABLE	-0.393	-0.444	0.450	-0.211	-
2	RESPONSIVE	- UNRESPONSIVE	0.368	0.537	0.413	0.214	-
3	OF SMALL DYNAMIC RANGE	- OF LARGE DYNAMIC RANGE	-0.478	-0.358	-	-0.231	-
4	NON INTIMATE	- INTIMATE	-	-	(0.583)	-	-0.229
5	OF SPLENDID TONAL BLENDING	- OF POOR TONAL BLENDING	0.347	0.573	-0.461	-	-
6	UNREVERBERANT	- REVERBERANT	-0.232	-	-	-	-
7	ROUGH	- SMOOTH	-	-	0.719	-	-
8	UNBALANCED	- BALANCED	-0.246	-0.357	0.513	-	-
9	COLD	- WARM	-0.270	-	(0.616)	-	-
10	FAINT	- LOUD	-0.331	-	-0.374	-	-0.492
11	LIVE	- DEAD	0.571	0.533	-	-	-
12	HAZY	- CLEAR	-	-0.810	-	-	-
13	DIM	- BRIGHT	-0.294	-0.696	-	-	-
14	NEAR	- DISTANT	0.201	-	-	-	0.667
15	DYNAMIC	- STATIC	0.550	0.374	-	-	-
16	UNBLENDED	- BLENDED	-	-0.413	0.508	-	-
17	LIGHT	- HEAVY	-0.378	0.248	-0.326	-	-0.223
18	PROFOUND	- SHALLOW	0.603	-	-0.293	-	-
19	OF POOR TONE	- OF RICH TONE	-0.420	-0.515	0.535	-	-
20	BRILLIANT	- DULL	0.346	0.758	-	-	-
21	MASSIVE	- SMALL	0.695	-	-	-	-
22	AMPLE	- MEAGRE	0.676	0.238	-	0.220	-
23	EVEN	- UNEVEN	-	0.315	-0.478	-	-
24	FULL BODIED	- THIN	0.765	-	-0.226	-	-
25	OF HARSH TONE	- OF SMOOTH TONE	-	-	0.723	-	-
26	HOLLOW	- FULL	-0.515	-	0.405	-	-
27	CLEAR	- MUDDY	-	0.829	-0.245	-	-
28	REMOTE	- NEAR	-0.234	-	-	-	-0.838
29	FADING OUT	- FADING IN	-0.312	-0.217	-	-	-0.305
30	DISTINCT	- BLURRED	0.193	0.740	-	-	-
31	FULL	- EMPTY	0.721	0.207	-0.237	-	-
32	EXPANDED	- CONTRACTED	0.618	0.232	-	0.368	-
33	ENVELOPING	- DISTANT	0.582	0.220	-	0.306	0.384
34	BLURRED	- CLEAR	-	-0.763	0.303	-	-
35	SPACIOUS	- CRAMPED	0.499	0.295	-0.200	0.405	-
36	TONELESS	- TUNEFUL	-0.287	-0.410	0.492	-0.249	-
37	RICH	- POOR	0.598	0.359	-0.425	0.262	-
38	LIMITED	- UNLIMITED	-0.421	-0.294	-	-0.658	-
39	EXTENDED	- SHORT	0.418	-	-	0.615	-
40	RESTRICTED	- UNRESTRICTED	-0.407	-0.258	0.200	-0.445	-0.226
41	WELL DEFINED	- ILL DEFINED	-	0.670	-0.250	0.241	-
42	VOLUMINOUS	- THIN	0.804	-	-	-	-
43	WELL PITCHED	- OUT OF TUNE	-	0.530	-0.369	-	-
44	FLAT	- SHARP	-	-0.403	-	-	-
45	RESONANT	- FLAT	-0.576	0.427	-0.195	-	-
46	MIGHTY	- SMALL	0.736	-	-	-	-
47	SONOROUS	- THIN	0.793	0.203	-	-	-
48	DRY	- RESONANT	-0.728	-0.290	0.235	-	-
49	WITHDRAWN	- EXPANSIVE	-0.630	-	-	-	-
50	VOLATILE	- CALM	0.339	0.221	0.332	-	-
51	BOOMY	- TINNY	0.561	-	-0.210	-	-
52	AMBIENT	- WITHDRAWN	0.611	-	-	0.341	-
53	DIMENSIONLESS	- FULL	-0.581	-0.216	0.349	-0.325	-
54	BRITTLE	- SMOOTH	-0.214	-	0.740	-	-
	Percentage of variance of initial factors		37	11	6	3	3

TABLE 2 : ROTATED FACTOR MATRIX; CONCERT A

No.	RATING SCALES		FACTOR 1 CLARITY	FACTOR 2 BODY	FACTOR 3 TONAL QUALITY	FACTOR 4 PROXIMITY	FACTOR 5 SPACIOUSNESS
	(-)	(+)					
1	VOLUMINOUS	- THIN	-	0.749	-	-0.292	-
2	BLURRED	- CLEAR	0.827	-	0.241	0.212	-
3	COLD	- WARM	-	-0.251	0.661	-	-
4	ENVELOPING	- DISTANT	-0.185	0.508	-	-0.589	-
5	LIMITED	- UNLIMITED	0.464	-0.356	0.280	-	0.445
6	DRY	- RESONANT	-	-0.505	0.236	-	-
7	DISTINCT	- BLURRED	-0.861	0.173	-	-	-
8	OF HARSH TONE	- OF SMOOTH TONE	0.298	-	0.802	-	-
9	FULL	- EMPTY	-0.325	0.647	-0.227	-0.189	-
10	CLEAR	- MUDDY	-0.873	-	-0.180	-	-
11	UNBALANCED	- BALANCED	0.213	-	0.438	-	0.388
12	FAINT	- LOUD	-	-0.521	-	0.381	-
13	EXPANDED	- CONTRACTED	-0.306	0.577	-	-0.244	-0.253
14	SONOROUS	- THIN	-	0.711	-0.352	-	-
15	HAZY	- CLEAR	0.828	-	0.275	0.210	-
16	NON INTIMATE	- INTIMATE	0.202	-	0.497	0.351	-
17	RESTRICTED	- UNRESTRICTED	0.496	-0.316	0.234	-	0.433
18	MIGHTY	- SMALL	-	0.743	-	-0.247	-
19	BRILLIANT	- DULL	-0.508	0.372	-	-0.267	-0.252
20	ROUGH	- SMOOTH	0.229	-	0.772	-	-
21	REMOTE	- NEAR	0.216	-0.273	-	0.813	-
22	SPACIOUS	- CRAMPED	-0.409	0.337	0.252	-	-0.541
23	FULL BODIED	- THIN	-0.231	0.682	0.235	-0.204	-
24	DIM	- BRIGHT	0.545	-0.300	0.273	0.242	0.257
25	OF POOR TONE	- OF RICH TONE	0.444	0.349	0.476	-	-
26	DISTANT	- NEAR	0.248	-0.350	-	0.790	-
27	EXTENDED	- SHORT	-	0.446	-	-	-0.233
	Percentage of variance of initial factors		43	10	7	5	3

TABLE 3 : ANALYSIS OF VARIANCE; COMPARISON BETWEEN TEST POSITIONS

CONCERT	FACTORS	BETWEEN POSITIONS		WITHIN POSITIONS		F-RATIO	signif.
		D.F.	MEAN SQ.	D.F.	MEAN SQ.		
A	1. CLARITY	20	3.043	219	0.573	5.31	0.00
	2. BODY	20	1.944	219	0.716	2.71	0.00
	3. TONAL QUALITY	20	1.862	219	0.741	2.49	0.00
	4. PROXIMITY	20	2.039	219	0.733	2.78	0.00
	5. SPACIOUSNESS	20	0.995	219	0.581	1.71	0.03
B	1. BODY	9	1.631	74	0.817	1.99	0.05
	2. CLARITY	9	2.628	74	0.737	3.57	0.00
	3. TONAL QUALITY	9	2.707	74	0.655	4.13	0.00
	4. PROXIMITY	9	1.453	74	0.860	1.69	0.10
	5. INTIMACY	9	2.019	74	0.560	3.60	0.00
C	1. BODY	9	1.884	74	0.776	2.43	0.01
	2. TONAL QUALITY	9	2.929	74	0.614	4.77	0.00
	3. CLARITY	9	4.586	74	0.439	10.44	0.00
	4. PROXIMITY	9	2.370	74	0.696	3.40	0.00