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Rooms for music education and rehearsal – evolution of their acoustic design and comparison of results between questionnaires and measurements

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ABSTRACT

When a new music education facility is being built, a high degree of standardisation in terms of acoustic treatment in rooms for music education and rehearsal is usually requested to make them suitable for the broadest possible range of use - although it is well known that it is impossible to find a room acoustic condition suitable for all instruments and voices. This case study looks into data (measurements and feedback from musicians via questionnaires) gathered from three recent projects for music universities and makes an attempt to throw some light to the question which range of instruments and voices can meaningfully be accommodated within a "standard room acoustic design" for a small ensemble room.

Keywords: Rehearsal, Practice, Acoustics

1. INTRODUCTION

It is one of the less questioned facts in room acoustics that it is impossible to find a room acoustic condition suitable for all instruments and voices – this fact is even mentioned in standard documents related to room-acoustics such as Norwegian Standard NS 8178:2014 "Acoustic criteria for rooms and spaces for music rehearsal and performance". Nevertheless, when new music education facilities are being built, the question: "how far you can go with a uniform room" usually comes up due to economical and organizational reasons. This paper tries to give some answers to this question. In recent years the authors were involved in several projects for new music university buildings. In three of the projects a dedicated "test room" was built to validate the room acoustic designs in the planning stage. By chance these rooms and their history of development were comparable. From this "accidentally" gathered pool of data the idea developed among the authors to analyze the data and try to find evidence related to the questions formulated in the following chapter.

2. QUESTIONS

Although the amount of data acquired from the previously mentioned projects is not insignificant, the authors understand that neither the methodology in acquiring the data nor the amount of data - or the way of analyzing the data - do conform to proper scientific standards. Nevertheless, an attempt has been made to give some explanations to the following questions:

a. Which range of instruments, voices and ensembles can be meaningfully accommodated in a "small ensemble room" (according to NS8178) having a given "standard" room acoustic design?
b. Which are the instruments, voices and ensembles that repeatedly can't be accommodated within a "standard" room acoustic design? (i.e. requiring "tailored" room acoustics.)
c. Which subjective acoustical impressions change most between the different room acoustic designs of the three test rooms?

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3. THE TEST ROOMS DESCRIBED

All "test rooms" were built as near as possible to the definitive rooms in terms of their shell and the room-acoustic interior. All test rooms were naturally lit via windows to the outside.

Table 1 – Geometrical Data of Test Rooms

	"Lucerne"	"Basle"	"Zurich"
Length [m]	8.0	8.0 (average)	7.5
Width [m]	5.7	5.1	3.5 (average)
Height [m]	2.9	3.4	2.8
Floor Area [m^2]	44.9 (square room)	40.4 (angled rear wall)	26.3 (angled side wall)
Volume [m^3]	130.3	137.4	73.5

During the development phase all three test rooms were - for quite different reasons in each project - fitted with two different room acoustical designs successively (denoted "Version 1" and "Version 2" in the following text). "Version 1" always was a "basic" design which was mainly driven by considerations other than purely acoustical ones, "Version 2" was an improved design with more focus on room acoustical quality.

3.1 The "Lucerne" test room

The "Lucerne" test room served as a test bed for around 45 similar rooms. Beside this "small ensemble rooms" the Lucerne project incorporates many other music rooms ranging in size and use from a chamber music hall to small practice rooms for individual musicians.

Brief description of Version 1 acoustic design: Ceiling: Strips of wood-fibre acoustic panels; Walls: Wood-fibre acoustic panels and angled membrane-absorbers on two walls, variable acoustic curtains on the other two walls; Floor: Cement

Brief description of Version 2 acoustic design: Ceiling: Acoustic panels incorporating wood-fibre surfaces together with angled perforated-panels and membrane-absorbers; Walls: Acoustic panels incorporating wood-fibre surfaces together with angled perforated-panels and membrane-absorbers on two walls, variable acoustic curtains on the other two walls; Floor: Cement

Figure 1 – "Lucerne" test room (left: Version 1, right: Version 2)

3.2 The "Basle" test room

The "Basle" test room served as a prototype for around 12 similar rooms. Beside this "small ensemble rooms" the Basle project incorporates around 35 other music rooms ranging in size and use from several small performance spaces of around 1500m^3 down to small practice rooms for individual musicians.

Brief description of Version 1 acoustic design: Ceiling: Mainly gypsum-moulded "QRD"-diffusors ("chessboard"); Walls: Perforated-panels and membrane-absorbers around the lower perimeter of the room, variable acoustic curtains; Floor: Parquet on floating cement slab

Brief description of Version 2 acoustic design: Ceiling: Wooden slats and porous absorption arranged in a "BAD"-diffusor structure; Walls: Perforated-panels and membrane-absorbers behind wooden slating in the middle- and lower-parts of the walls, porous absorption behind fabric on the upper parts of the walls; Floor: Parquet on floating cement slab

Figure 2 – "Basle" test room (left: Version 1, right: Version 2)

3.3 The "Zurich" test room

The Zurich test room served as a prototype for close to 100 similar rooms. The project incorporates over 200 music rooms ranging in size and use from a large 5000m^3 chamber music hall to recording studios, smaller performance spaces and down to small practice rooms for individual musicians.

Brief description of Version 1 acoustic design: Ceiling: Wood-fibre acoustic panels covering approx. 2/3rd of the ceiling; Walls: Variable acoustic curtains along one long and one short wall; Floor: Parquet on floating cement slab

Brief description of Version 2 acoustic design: Ceiling: Wood-fibre acoustic panels covering approx. 2/3rd of the ceiling; Walls: Perforated-panels and membrane-absorbers along one long wall with variable acoustic curtains in front of them; Floor: Parquet on floating cement slab

Figure 3 – "Zurich" test room (left: Version 1, right: Version 2)

4. "METHODOLOGY" OF DATA ACQUISITION

As mentioned in chapter 2 the acquiring of the data for this case study did not follow a predefined plan but was driven by the needs of the individual projects. Nevertheless, the basic methodology was the same for all tree test-rooms.

4.1 Questionnaires

Once built and fully fitted-out, the rooms were handed over for a defined time span to the professors and students of the respective music universities to be used for practicing and teaching. Questionnaires were issued and people encouraged to give their opinion about the acoustical quality of the rooms via multiple-choice questions as well as the possibility to include additional written comments. The questionnaires were not based on scientific practice for subjective listening tests but on the idea to present a small set of questions in "musicians-language". As there was no predefined group of test persons, a formal introduction wasn't possible and the questions had to be self-explanatory. The main questions were as follows:

1. How do you rate the overall acoustical quality of the room? (very good, good, sufficient, insufficient)
2. How do you perceive the loudness while playing in the room? (too loud, appropriate, too weak)

3. How do you perceive the reverberation of the room? (too reverberant, appropriate, too "dry")
4. How would you describe the timbre of the room? (too "dark"/muddy, balanced, too "bright"/harsh)
5. How do you perceive the musical transparency in the room? (clear/transparent, blurred/not transparent)
6. How do you perceive the bass in the room? (too weak, appropriate/musically supporting, too strong/"boomy")

Table 2 – Overview of questionnaires received

Questionnaires received	Version 1	Version 2	Remarks
"Lucerne"	63	66	Classical & jazz musicians, mainly playing solo
"Basle"	23	11	Mainly jazz musicians, solo & ensembles
"Zurich"	23	19	Classical & jazz musicians, mainly playing solo

For the purpose of this case study it has been decided not to differentiate if the musicians played solo or in ensembles because "small ensemble rooms" shall be capable to accommodate both cases.

4.2 Acoustic Measurements

A full set of acoustical measurements was taken in all test-rooms for both versions of the acoustical designs. Additional measuring sessions covered the various states of the rooms regarding their variable acoustics (curtains) and their furnishing. While, for the actual design work on the rooms, a set of acoustical parameters was calculated from the acquired impulse responses, only reverb time over frequency shall be considered for this case study. Mainly because this is still one of the key parameters used in recommendations and standards on room acoustics for music rehearsal rooms.

5. Results

5.1 Reverb Times

In the following diagrams the reverb time over frequency is shown for Version 1 and Version 2" acoustic designs of the respective test-rooms.

Figure 4 – Reverb Times of the three test-rooms (blue curves show Version 1, red curved show Version 2, dotted lines show respective reverb times with acoustic curtains in full use)

Remark regarding Reverb Times in "Basle" test-room: The pronounced rise in reverb time around 500Hz in Version 1 was due to a cluster of narrow-band resonances in the Z-axis of the room. These resonances developed just below the cut-off frequency of the "QRD"-diffusors used on the ceiling. The reverb times shown are therefore not valid in the 250&500Hz octave bands.

5.2 Questionnaires

The following three Figures show results obtained from questionnaires for the tree test-rooms.

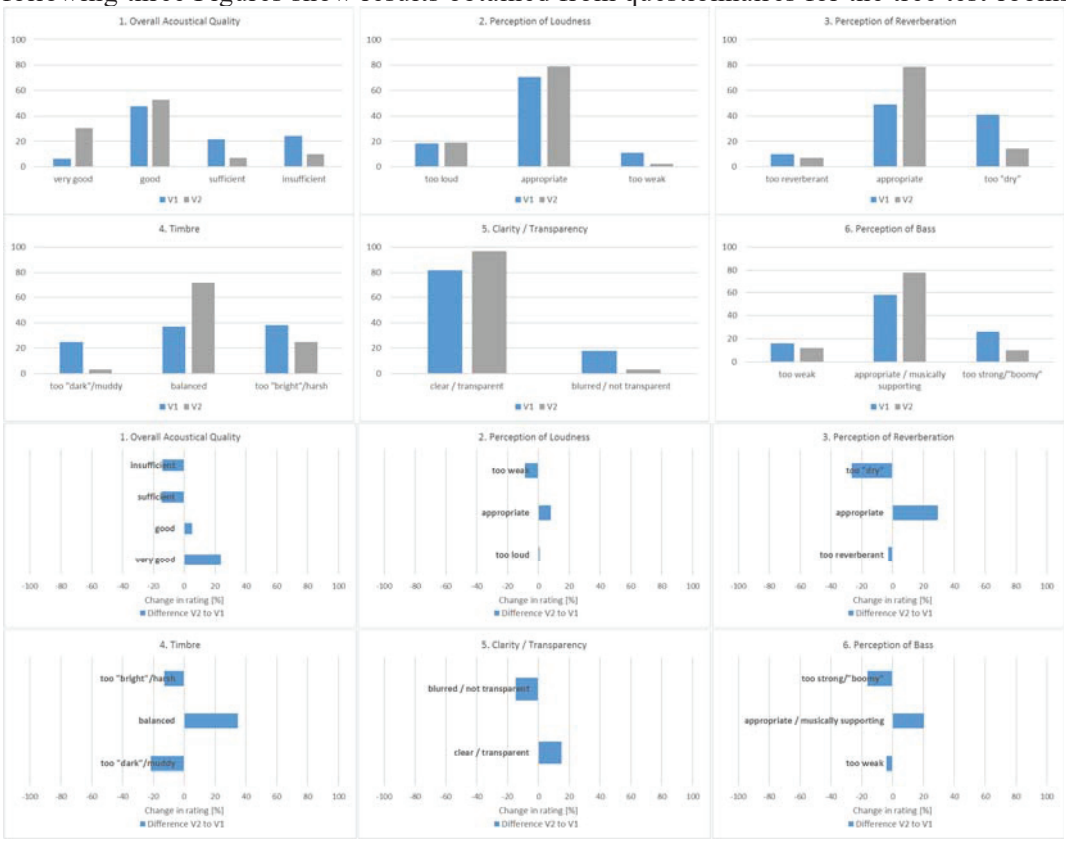

Figure 5 – Results of questionnaires for "Lucerne" test-room (the six upper tables show absolute ratings, the six lower tables show change in ratings)

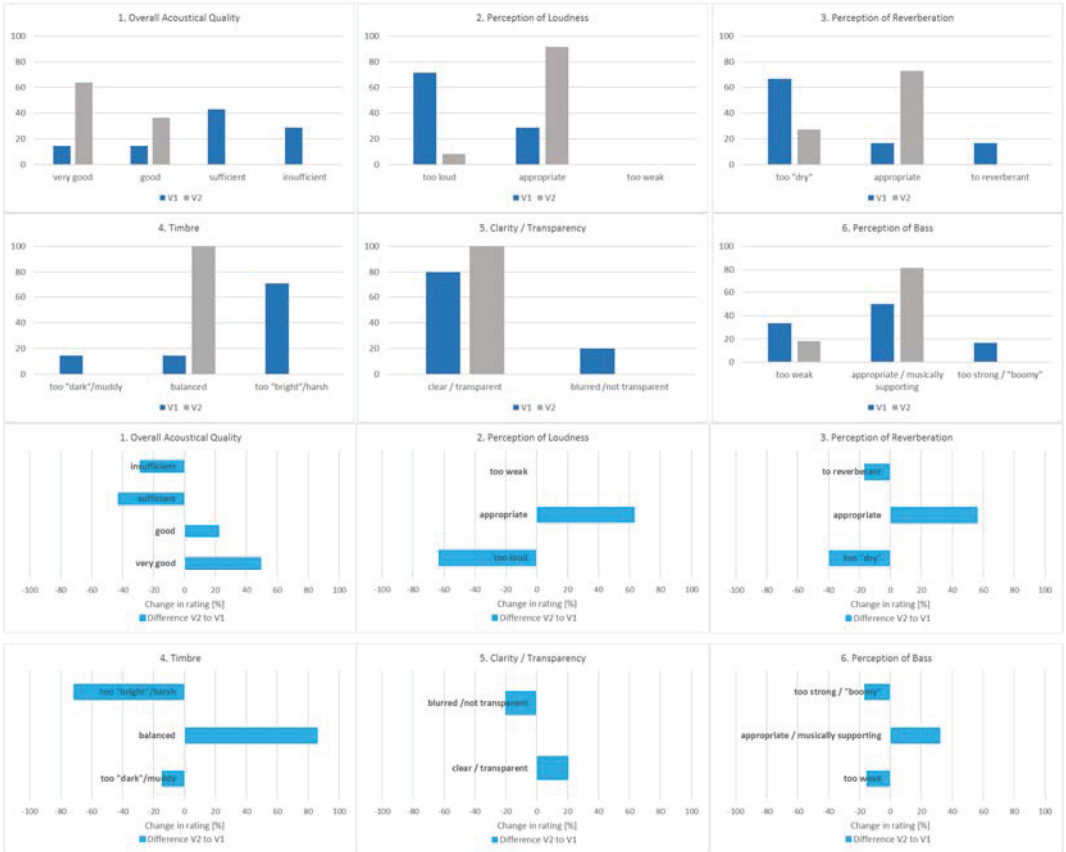

Figure 6 – Results of questionnaires for "Basle" test-room room (the six upper tables show absolute ratings, the six lower tables show change in ratings)

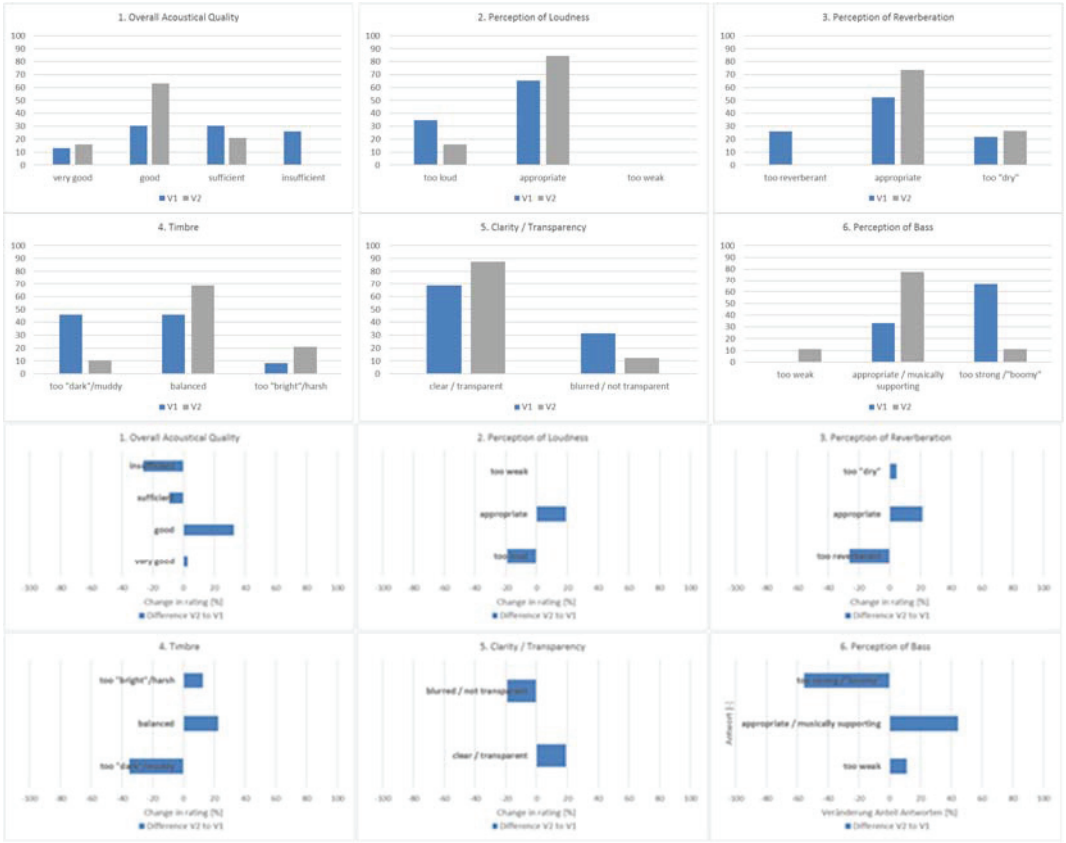

Figure 7 – Results of questionnaires for "Zurich" test-room (the six upper tables show absolute ratings, the six lower tables show change in ratings)

6. INTERPRETATION

6.1 "Lucerne" test room

Version 1 of the room was rated at 70% "sufficient"/"good" but with a remaining 25% considering the room "insufficient". Negative comments coming mainly from piano players ("too loud" and "boomy") vocalists and woodwinds ("too dry").

For Version 2 it was decided to increase the reverb time to give better support to "weak" acoustic instruments and voices while at the same time make it more even over frequency. Diffusion was improved to provide a smoother sound despite the increased reverb time. This resulted in a better acceptance with "good/very good" ratings reaching 80% and had a marked influence on the ratings of many groups of instruments - especially piano players considered the loudness in the room more appropriate despite the increase in reverb time.

Version 2 still shows "insufficient" ratings in overall acoustical quality. From the available data two main groups of instruments could be identified: Musicians playing classical acoustic guitar and woodwinds (such as oboe) criticized the room for not supporting low notes and "resonance" enough. These instruments seem to benefit from moderate resonances in the room. The other group of musicians not content with the rooms were mainly classical percussionists which considered the room still "too loud" even with curtains fully used.

6.2 "Basle" test room

In Version 1 the overall acoustical quality of the room was rated "sufficient/good" by almost 60% of the musicians but there was a 30% "insufficient" group. Negative comments mainly coming from ensembles and musicians with louder wind instruments such as saxophone, trombone etc. considering the room "too loud" and "too bright/harsh". Singers and musicians playing softer wind instruments considered the room "too dry".

For "Version 2" it was decided to introduce a quite moderate level of reverb time but to provide "liveliness" for the players by providing a dense pattern of early reflections from walls and ceiling. This was achieved by positioning wooden slats in front of most of the acoustical treatment on the walls and incorporating a "BAD"-diffuser on the ceiling which provides diffusion as well as

absorption. Variable acoustics (curtains) were deliberately kept to a minimum. This design worked surprisingly well for ensembles as well as solo musicians. "Insufficient" ratings regarding overall acoustical quality disappeared while "very good" ratings went up to over 60%. Most significant differences were in terms of perceived loudness and timbre, both parameters reaching almost full consent. The remaining negative comments mainly came from vocalists and trumpet players rating the room as "too dry" while drummers and electric-bass players still rated it as "too loud".

6.3 "Zurich" test room

The "Zurich" test-room in Version 1 was rated in the "sufficient to very good"-range by 75% of the musicians. 25% considered the room as "insufficient" (the comment "unplayable" appeared several times in the optional written comments). Negative comments were issued mainly by musicians playing piano, electric-bass and trombone. The significant increase in low frequency reverb time provides an explanation.

The Version 2 acoustic design incorporated increased low- and low-mid frequency absorption. It can be seen from Fig. 4 that the "insufficient" ratings in overall acoustic quality disappeared and a shift in "Perception of bass" can be observed from "too strong" to "appropriate". As observed also with the "Lucerne" test-room, some conflicting ratings in various categories remain. Looking at the data it was found that conflicting ratings were issued even by musicians playing the same instrument - some piano players rated the "timbre" as "too bright/harsh" while others rated it "too "dark"/muddy". An explanation could be the inappropriate use (or non-use) of the acoustic curtains (the questionnaires asked to give information about the use of the curtains). From Fig. 4 it can be seen that the relatively large area of variable curtains in relation to the size of the room has a significant influence on the mid- and high frequency reverb time.

7. CONCLUSIONS

From the results obtained from the three test-rooms it can be seen that it is possible to accommodate a quite broad group of instruments, voices and ensembles in a small ensemble room with a given "standardized" acoustic treatment. A more refined acoustic design such as the one applied to the Version 2 "Basle" room (see 3.2) seems to work particularly well despite its lack of variable acoustic elements.

Musicians repeatedly "left behind" in the test-rooms can broadly be characterized as three groups:

1. Musicians playing loud/"bass-heavy" instruments such as drums & classical percussion, electric-bass, electric-guitar, trombones, tuba etc.
2. Vocalists and musicians playing soft wind instruments such as flutes, oboe etc.
3. Musicians playing "plucked" string instruments such as acoustic-guitar, harp, harpsichord etc.

These tree groups of musicians usually need rooms with a more tailored room acoustic design. The first group needs rooms with significant broadband damping (with measures to preserve some "liveliness"). The second group prefers quite reverberant rooms which may even have a pronounced rise in low-frequency reverb time to "support" the sound. The third group is quite unique and may require a room acoustic design almost "contractionary" to usual practice. As the dynamic range and the ability to "sustain" the notes of their instruments is limited, the players of these instruments can benefit from a quite pronounced low frequency reverb time – even making good use of (usually strictly avoided) resonances in the room right up to the low-mid frequencies.

After analyzing the data from the three test-rooms there is quite some evidence that the incorporation of large areas of variable acoustic curtains (the usual way to provide economical and easy-to-use variable acoustics) does somewhat extend the range of musicians for which the room is suitable, but not as much as usually intended or expected. For example, the significant damping of a room in the mid- and high-frequency range provided by acoustic curtains does not solve the loudness problem with instruments having a substantial low-end performance (drums, percussion, bass, concert grand etc.). In such cases the musicians often rated a room still as "too loud" because the level produced at lower frequencies is not significantly affected by the curtains. Also the more or less unavoidable frequency imbalance caused by large scale usage of curtains (or other lightweight, easy-to-move porous absorption) is often distorting the reverb-time over frequency - and therefore the timbre of the room - to an extent as to be disturbing for the musicians playing in the room.

Finally, the sensible use of acoustic curtains can – unfortunately - not generally be expected. Conflicting ratings in acoustic quality such as mentioned in Chapter 6 can sometimes be traced down to this circumstance.

In practice the need to provide rooms with a tailored acoustics for the above mentioned groups of musicians leads either to the incorporation of elaborate "full-bandwith"-variable acoustics in at least some rooms of a facility (a strategy which is often declined in projects due to the cost implications) or to provide a palette of rooms with suitably adapted acoustics beside the "standard"-rooms. All three music universities mentioned in this study did follow the later route.

The authors will continue to encourage the building of test-rooms in future projects for music education facilities. They provide an ideal test bed for the development of acoustic designs and do encourage acousticians to try new concepts on "safe ground". Test-rooms also offer the possibility to gather feedback from the musicians as well as involving them in the project. The positive effects on the outcome and acceptance of a new facility by involving the musicians and listening to their needs and comments shall not be underestimated.