Bergen, Norway

BNAM 2010

May 10-12

Sound levels for trumpet players in practice rooms

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The binaurally measured sound level at the ears of trumpet players differ only slightly between different practice rooms, but the subjective perception of the sound level differs more. Legislation for maximum sound exposure levels for musicians at work is $L_{EX,8h}$ 85 dB(A) [1]. Trumpet players are typically exposed to L_{eq} 95 dB(A) while playing in practice rooms. The risk for hearing problems, like tinnitus and hyperacusis, is also influenced by stressors. The perceived sound level is therefore important from a sound health point of view. The subjective sound level seems to be influenced by the character of the sound (*warmth* or *Bass-Ratio*) and the location and amount of absorbing surfaces in the rooms. Small practice rooms are subjectively not necessarily rated louder than larger ones as long as they have enough unfolded absorptive drapes at the walls.

1 Introduction

The research of the acoustics in small rehearsal rooms is a rather neglected topic, compared with the efforts made for the performance and listening acoustics, in concert halls. Studies have been made for practice rooms, but often focusing on sizes of floor area above 100 m^2 [3]. Often room size for own practice is in the range of 8 to 26 m^2. In order to improve one's musical skills, the acoustical characteristic of the practice room is of great importance. The preferred characteristic of the practice rooms is highly complex, and varies a lot between different instruments [9] and even within instruments and genres. For most musicians the way of playing is affected in some way by the feedback from the room. This adjustment can be both good and bad, depending on the situation. A good musician should be able to perform in most kinds of acoustical environments, from churches to outdoors to a small jazz club. For the best results in a concert the musician should be able to adapt to the acoustics, but in some cases of "bad acoustics" also be able to trust the "inner" systems of playing, being indifferent of the environment. The interest of this paper is to investigate the differences in measured and perceived loudness in practice rooms.

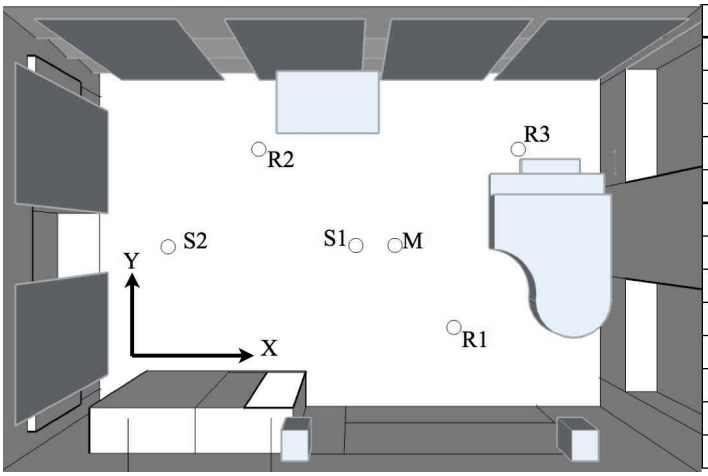
2 Approach

The approach was divided in three parts in this study: *Acoustic parameter measurements*, *Measurements of sound levels and spectra with the musicians playing* and *Subjective judgements and interviews*.

Two rooms were chosen for the study, see Figure 1 and Figure 2, both primarily used by brass students. **Room 1** has the dimensions (*L*W*H*) 6.3 m*4.3 m*3.2 m, whereas **Room 2**, has the dimensions 4.7 m*1.9 m*3.2 m. Room 1 has six drapes whereas Room 2 has four absorptive drapes. The rooms where arranged in two ways; drapes fully folded and drapes fully unfolded. This leads to the four configurations, which is presented in Table 1. To limit the study a number of parameters had to be fixed; such as the position of the trumpet player and direction of the trumpet. The positions used to evaluate acoustic parameters while playing are noted M (musician) and S1 (trumpet bell), which is presented in Figure 1 and Figure 2.

Table 1: Notation and relations of room size and drape arrangement

	Large room	Small room
Folded drapes (min absorption)	Room 1a	Room 2a
Unfolded drapes (max absorption)	Room 1b	Room 2b



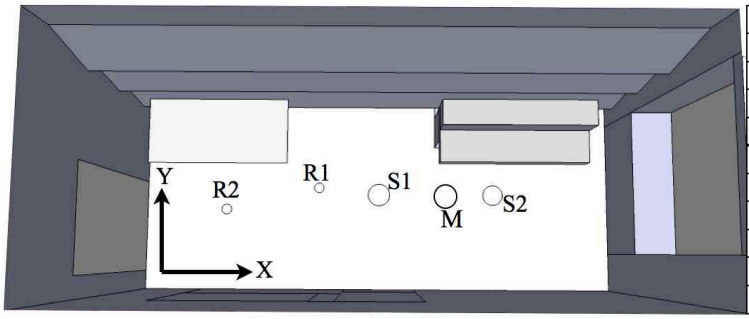
[m]	X	Y
S1	3.23	2.0
S2	0.86	2.0
R1	4.46	1.0
R2	2.0	3.25
R3	5.27	3.25

DISTANCE [m]	
S1/S2	3.86
S1/R1	1.61
S1/R2	1.72
S1/R3	2.38
S2/R1	3.74
S2/R2	1.68
S2/R3	4.58

Figure 1: Room 1 with drapes and measurement positions marked out. The door is to the left.

Position M was excluded in all ISO measurements. The position of the musician was chosen 2/3 of the rooms' length from the door, centred in width and pointing towards the door. The music stand was positioned to the side of the musician while playing.

The subjective measurements were made in the following order: First the musician was presented to a questionnaire and the practice rooms. Then the musician was able to try out the acoustic and fill in the questionnaire for each room variation. After that, a binaural recording for each room variation and finally an interview was carried out.



[m]	X	Y
S1	2.35	0.95
S2	3.51	0.95
R1	1.74	1.02
R2	0.80	0.80

DISTANCE [m]	
S1/S2	1.16
S1/R1	0.61
S1/R2	1.56
S2/R1	1.77
S2/R2	2.71

Figure 2: Room 2 without drapes and measurement positions marked out. The door is to the left.

2.1 Acoustic parameter measurements

Measurement positions are shown in Figure 1 and Figure 2 where a dodecahedron loudspeaker and a microphone with omni directional characteristics were used. Parameters measured in accordance to ISO 3382 presented in this paper are T_{30} and *Bass-Ratio, BR*, [5] the other measured ISO parameters of interest will be investigated in a later stage. The rooms were arranged according to Table 1. Since Room 2, was very small a modification was made to the ISO standard, whereas positions were chosen with respect to the obtainable space, two height positions were used, 1.15 m and 2.0 m from the floor. Further binaural measurements will be included in the complete study, evaluating results using a source where the directivity is more similar to a trumpet [4, 6, 7, 8].

2.2 Measurements of sound levels and spectra with the musicians playing

Binaural recordings were made in order to evaluate the perceived and measured differences. Binaural measurements were only evaluated for four out of nine musicians due to technical problems. Figure 3 shows one of the musicians during the acoustic measurements on playing, recorded with miniature microphones (DPA 4060) at the ears. The trumpet players played two predefined musical pieces from Arban's Complete Conservatory Method for Trumpet, piece 13 (referred to as piece one), and 28 (referred to as piece two), which both have a duration of approximate 35 seconds. The pieces include both fast and slow parts. Piece one did not have a dynamic indication, but piece two had, (*mezzo-piano* and *mezzo-forte*). The rooms were arranged according to Table 1.

Figure 3: One of the musicians playing while binaurally recorded in Room 1b.

2.3 Subjective Judgements and interviews

Nine trumpet players participated in the subjective investigation. The subjective judgements were investigated in two ways; a questionnaire and an interview. The musicians had a large distribution regarding age, profession, music style and gender. It was important to fully explain the words and concepts used in the questionnaire to the musicians. At the same time, it was important not to bias the musicians before the tests. To find a balance between these opposing interests is a delicate task.

The interview was carried out in the end of each session where further discussions made it possible to pick up additional information and potential difficulties that the subject might have experienced [2]. The questionnaire containing ten questions was created using a nine-point hedonic category scale [2] presented in Figure 4 below.

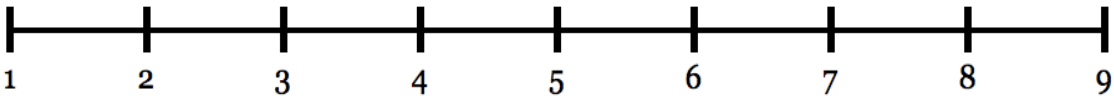


Figure 4: The figure shows the nine-point hedonic category scale.

Questions 1 to 10 are displayed in the list below. This paper will primarily evaluate question 2 and 3, since those questions are directly related to the interests of this paper, further work will include the other questions.

1. How important is the acoustic environment in practice rooms? From *Not at all* to *Very important*
2. How good is the room for rehearsing? From *Bad* to *Excellent*
3. How do you perceive the sound level in this room? From *Too low* to *Too high*
4. How strenuous is it to play in this room? From *Not at all* to *Much*
5. How do you rate your ability to play dynamical? From *Small* to *Large*
6. How good are the rapid parts perceived? From *Bad* to *Excellent*
7. How good are the slow parts perceived? From *Bad* to *Excellent*
8. How do you perceive the support from the room? From *Bad* to *Excellent*
9. How would you rate the balance between hard/soft? From *Too soft* to *Too hard*
10. Describe the room coloration with a colour.

3 Results

3.1 Acoustic parameter results

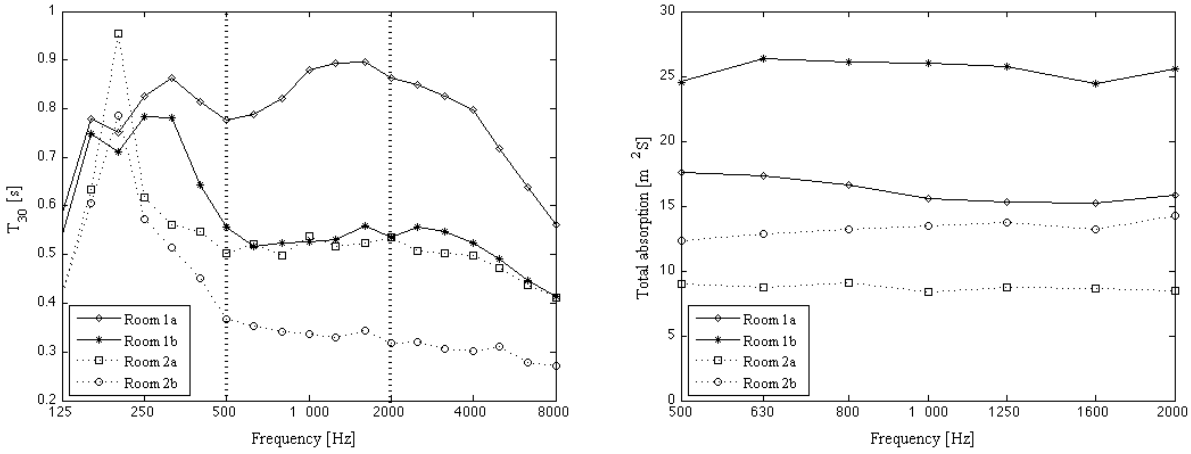


Figure 5: The left figure shows mean T_{30} for the four different rooms in third-octave bands and the right figure shows the total absorption area in the four different rooms, note the different x-axis scales.

The mean T_{30} for the four rooms are presented in Figure 5, where the dotted vertical lines indicate the range used in the right hand graph. With Schroeder frequencies as shown in Table 2 one can see that both room size and drape arrangement influence the frequency where the sound field becomes diffuse. However the perception of a reverberant decay is possible also for low frequencies. It is therefore assumed that the *BR* still can be evaluated in our case.

Table 2: Schroeder frequency, Bass-Ratio, T_{30} and Total Absorption (mean for 500Hz-2kHz) for the four rooms

	Room 1a	**Room 1b**	**Room 2a**	**Room 2b**
Schroeder frequency [Hz]	189	167	273	240
BR [-]	0.98	1.24	1.05	1.39
Total Absorption [m^2S]	16.2	25.5	8.7	13.3
T_{30} [s]	0.85	0.54	0.52	0.34

3.2 Measured sound levels and spectra with the musicians playing

Table 3 shows the binaurally measured $L_{A,eq}$. Noticeable sound level difference limen is commonly around 1 dB. The binaurally measured sound levels do not differ significantly between the ears.

Table 3: Measured $L_{A,eq}$ while playing (average right/left ear).

Trumpet Player	**6**		**7**		**8**		**9**	
Piece	1	2	1	2	1	2	1	2
Room 1a [dB(A)]	98.4	95.8	98.5	94.6	97.8	93.4	95.8	94.9
Room 1b [dB(A)]	98.1	94.6	95.7	93.4	95.6	92.9	95.2	94.6
Room 2a [dB(A)]	99.7	95.8	96.7	93.5	97.5	93.8	96.8	96.1
Room 2b [dB(A)]	99.7	95.9	95.6	93.5	96.3	93.8	96.2	95.2
Difference max-min [dB(A)]	1.6	1.3	2.9	1.2	2.2	0.9	1.6	1.5
Max $L_{A,eq}$ in Room	2a, 2b	2b	1a	1a	1a	2a, 2b	2a	2a
Min $L_{A,eq}$ in Room	1b	1b	2b	1b	1b	1b	1b	1b
Average difference for all trumpet players: 1.6 dB(A) Average level 96 dB(A).								

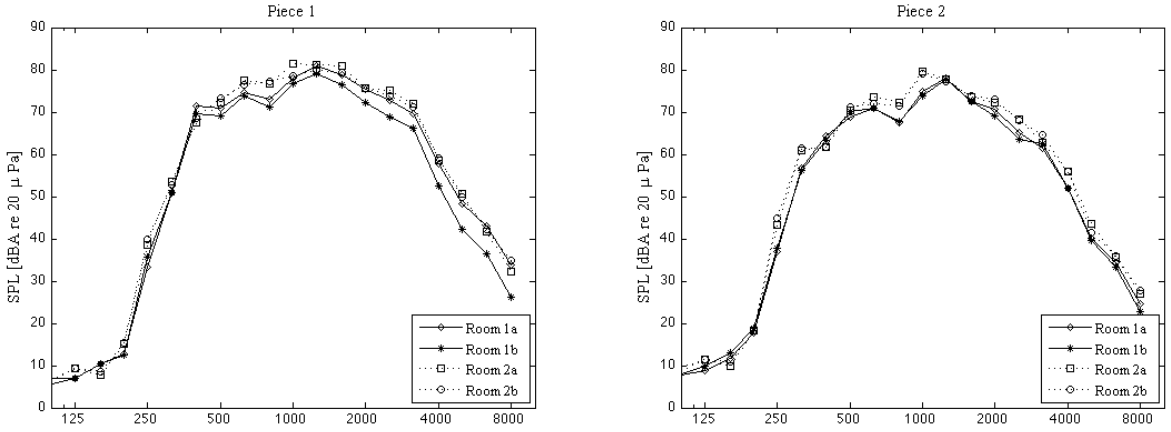


Figure 6: Frequency spectra of the two musical pieces in the different rooms. Only right channel is showed.

In Figure 6 the frequency plots are displayed only for musician no 8. The second musical piece had a dynamic indication and also appears to have less level difference between the room variations.

3.3 Subjective results

The trumpet players were divided into genre subgroups; Classic (C, black) and Jazz (J, white) and also divided into three subgroups regarding "musical level"; professional (Pr, circle), amateur (Am, square) and student (St, triangle). In Figure 7, the answers to question no 2, the overall practice quality of the rooms are presented. Generally a big deviation can be seen between the different trumpet players. An overall increase of ratings can be seen for Room 1b. The mean values and standard deviation can be seen in Table 4. The rating shows a large deviation between the different trumpet players, especially for Room 2a. A comparison between the *BR* and the answers of perceived loudness shows (with a significance level of 0.052 in Table 4), that a room with low *BR* is rated louder than a room with high *BR*.

The classical trumpet players seem to dislike the small rooms in a larger extent than the jazz trumpet players, which also corresponds well with our impression from the interviews.

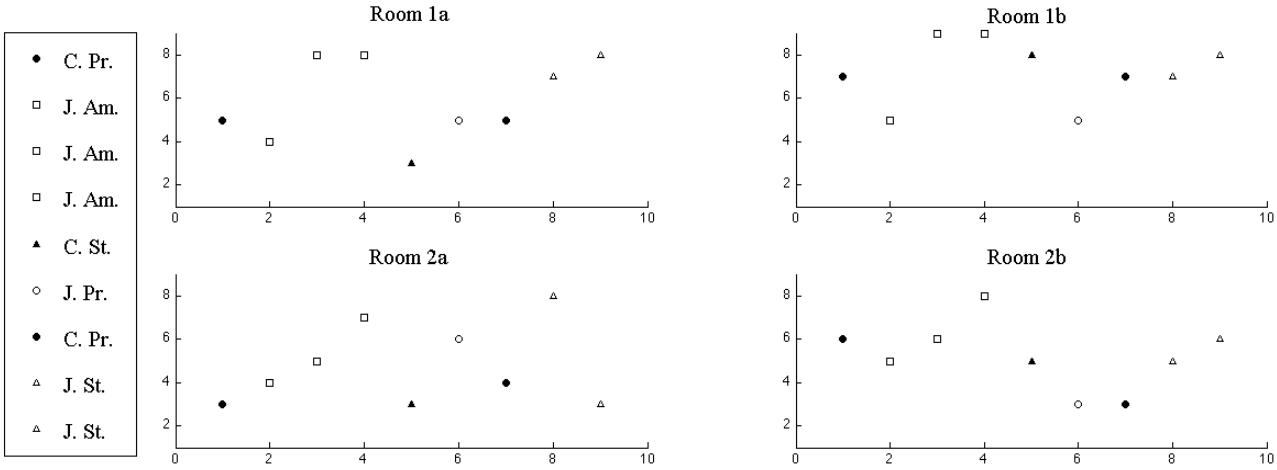


Figure 7: Answers to question 2: *"How good is the room for rehearsing?"*, rated from *Bad (1)* to *Excellent (9)*, where x-axis is the musician number and y-axis is their rating for each room.

In Figure 8, the answers to question 3 are presented. The rooms with the drapes unfolded, Room 1b and 2b, generally shows lower values than the rooms with the drapes folded. Room 2a scatters the trumpet players most, see Table 4.

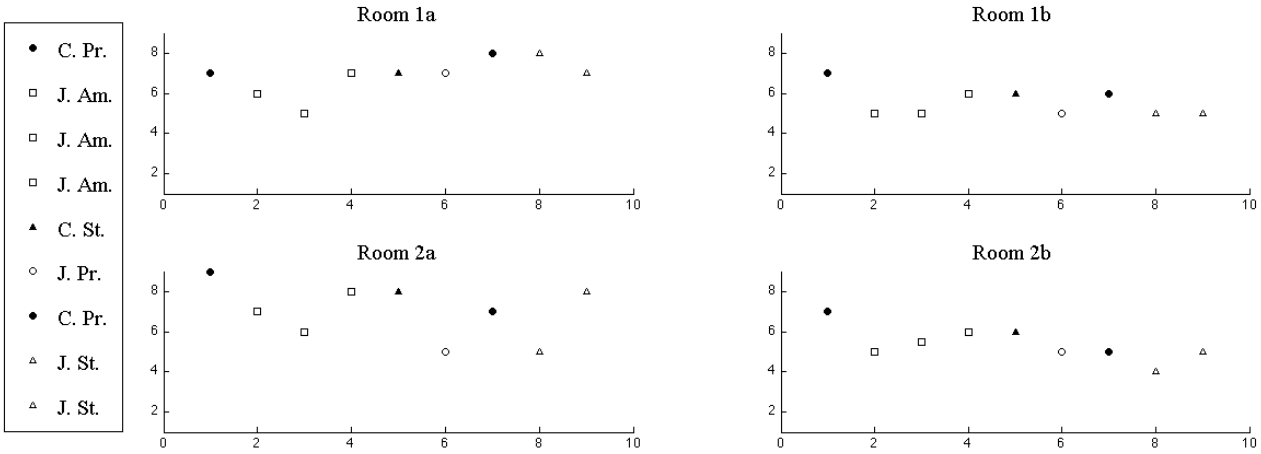


Figure 8: Answers to question 3: *"How do you perceive the sound level in this room?"*, rated from *Too low (1)* to *Too High (9)*, where x-axis is the musician number and y-axis is their rating for each room.

Table 4: Comparison of Bass-Ratio, subjective results and standard deviation from Questions 2 and 3.

	Room 1a	**Room 1b**	**Room 2a**	**Room 2b**
$\mathbf{BR_{mean}}$	0.98	1.24	1.05	1.39
$\mathbf{Q2_{mean}}$	5.9	7.2	4.8	5.2
$\mathbf{Q2_{STD}}$	1.9	1.5	1.9	1.6
$\mathbf{Q3_{mean}}$	6.9	5.6	7.0	5.4
$\mathbf{Q3_{STD}}$	0.9	0.7	1.4	0.9

The trumpet players were asked to rank the rooms during the interview and the result can be seen in Figure 9. Room 1b (Large room with max abs.) is clearly more favourable than the others, and Room 2a seems to divide the trumpet players into two groups, those who like it and those who don't. Room 2 (including both 2a and 2b) is chosen as the least liked room (4th place, white bar) to practise in by all participants. Room 1a is regarded as neither the best nor the worst room but something in between.

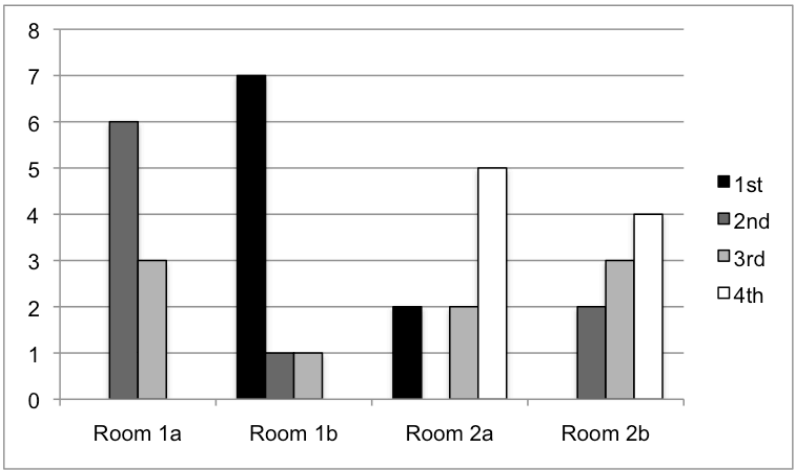


Figure 9: Ranking of the rooms. Here, y-axis stands for number of votes.

4 Discussion

In this study sound level has been evaluated by; measured ISO parameters, binaural measurements and subjective judgements. These three approaches of performing investigations of sound level end up with different results. Apparently, more absorption area (correlated to T_{30} and room volume) doesn't always lead to an expected reduction of $L_{A,eq}$ for the musician. There seems to be a connection between perceived sound level and *BR*. Higher values of *BR* results in a slightly lower measured and clearly lower perceived sound level. The latter can be due to that the instrument feels softer and warmer in its tone. From the binaural measurement on playing, there are only small changes of measured $L_{A,eq}$, the average difference between all situations is 1,6 dB. The small differences at the ears indicates either that the trumpet players adjust they style of playing in the different rooms *or more likely* they are simply standing in the dominating direct sound field of the instrument. The two musical pieces differed in one aspect, namely that second piece had dynamic indicators. From the result one can see that the difference was smaller for the second piece than for the first piece. It seems like the trumpet players stabilize the output level more if they get a dynamic indication.

Swedish legislation for maximum sound exposure levels for musicians at work is L_{eq} 85 dB(A) measured during 8 hours a day, five days a week [1]. The study shows that trumpet players are typically exposed to about L_{eq} 95 dB(A) (free field corrected value) in practice rooms. This means that the effective musical rehearsal time should be kept to less than 1 hour a day, 5 days a week. Sound levels according to the subjective investigation show that the room size is less important, and stronger sound levels were perceived while playing in rooms without drapes. The standard deviation of perceived sound level (Q3) is smaller than the standard deviation of the overall practice quality (Q2) of the rooms. This result implies that the overall practice quality is a much more complex question than perceived loudness and varies more between the different musicians, probably due to being more related to personal preferences and would therefore need a broader approach.

5 Conclusions

All tested room situations are rated slightly higher than the middle value from Bad to Excellent (in Q2). Room 1a and 1b are best according to the subjective results. Most surprising results are yielded for Room 2a, which is both rated best and worst by the musicians. The rooms without drapes in both sizes, Room 1a and 2a, gives slightly higher measured and clearly higher subjective sound levels. The sound level in these rooms (1a and 2a) is equally rated as higher than optimum (Q3). For future planning therefore larger room sizes with relatively more drapes could be an improved solution. The small room can be seen as an acceptable complement to the larger and should not necessarily be rejected due to issues regarding sound levels, but possibly due to it's generally lower quality. More investigations need to be made in order to clarify what makes the rooms with drapes more preferred.

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