A Comparative Study on Indoor Sound Quality of the Practice Rooms upon Classical Singing Trainees' Preference

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Summary
In music schools, indoor sound quality is a necessity since students and trainees are learning and improving their skills by listening to their own instruments or voices. This study investigates how the perceived singing effort influences the singer preferences in individual music practice rooms as it is focused on as well as the optimum reverberation time. Three different room settings were determined according to the amount of reverberation time, consecutively (from dead to live). Data was taken from 30 classical singing trainees using questionnaires at Bilkent University, Faculty of Music. Results have shown that the majority of trainees choose a room setting with 0.8 s RT to practice in.

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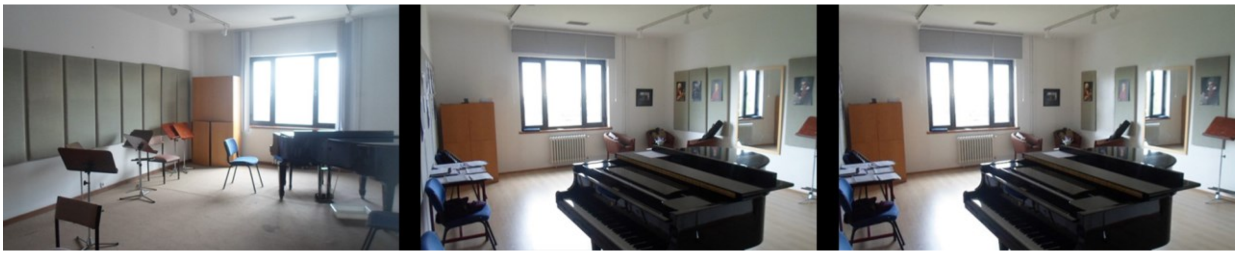
1. Introduction

Architectural acoustics on concert halls have been studied for both musicians and listeners. However, music practice rooms for musicians require a lot of attention to detail as well. The reasons are that musicians learn and improve their skills by listening to their instruments [1], and poor acoustics may result in vocal strain [2] or hearing damage [3]. Considering the amount of time that musicians spend in these rooms, 40 hours in a week [4], focusing on these aforementioned spaces became a necessity.

Music practice rooms mostly vary in size and design depending on the main aim of the room [5]. However, they are predominantly designed to be small. Reverberation time, in this manner, may not be the initial consideration for such rooms. Acoustics should be focused on eliminating the problems that rise from room geometry and size first. At low frequencies, in small rectangular rooms, the room modes spacing can be large. If the spacing is greater than 1/3 octave, it results in unwanted peaks and valleys in the room [6]. The effect of room resonances should be minimized to weaken room modes by applying absorbent surfaces in small rooms. After solving the critical problems that emerge from room geometry, and size, the designer can finally focus on the reverberation time. Reverberation time (RT) is an important acoustical parameter for room acoustics. A room with a particular reverberation time could not be suitable for all musicians' requirements. For instance, a cellist, a drummer, a trumpeter, and a classical singer cannot use a single room setting with a certain reverberation time because the characteristics of their instruments and accordingly their frequencies are quite different. For this reason, requirements of musicians in these rooms should be determined separately.

In the previous studies, the effects of reverberation time in practice rooms on instrumentalists were studied [4, 7, 8, 9]. Most of them focused on hearing problems. As for other studies focused on RT preferences of musicians, Lamberty [4] investigated the user musicians' RT preferences. Majority of music students noted that they prefer a live room with 0.9 s to a 'dead' room with 0.5 s and a considerable number of students preferred a room with RT something midway. Nelson [10] measured



Room Setting 1 Room Setting 2 Room Setting 3

Figure 1. Photographs of three different room settings

RT of vocal practice rooms in a university campus by using impulse response. The most preferred practice rooms were found to have stronger reflections and a longer RT.

Optimum acoustical conditions may differ from one classical singer to another. Accordingly, perceived singing effort may be a determinant factor to estimate how the reverberation time should be in music practice rooms. Foot [11] investigated the effect of dead and live conditions on the intensity of singers' vocal effort. According to auditors' perception, vocal effort intensity increased significantly in absorbent conditions.

Perceived singing effort has not yet been tested with classical singing trainees' RT preferences. Furthermore, based on the doctoral study Hom performed [12] on choristers, in a similar case, future research may seek to explore possible correlations between room conditions and singer behavior and their preferences.

The aim of this study is to focus on how the perceived singing effort influences the RT preference of classical singing trainees upon individual singing practice rooms. Furthermore, this study investigates the optimum RT of a practice room according to classical singer trainees' satisfaction levels for individual usage.

2. Case Study

Singing practice rooms for individual usage in Bilkent University Faculty of Music & Arts in Ankara, Turkey were chosen for this study. Two identical singing practice rooms were determined. Their dimensions are 7.3m*5.4m*3.2m (L*W*H) and their volumes are 128 m^3. There are absorbent panels with dimensions of 1.4m*0.60m*0.03m (L*W*H). The study was divided into two parts: acoustical parameter measurements via simulation software, and subjective evaluations through questionnaires and open-ended interviews.

2.1. Acoustical Parameter Measurements

In one of the singing practice rooms, the distribution and the number of absorbers on the walls were changed and a new additional setting was created.

Therefore three different room settings were prepared, as seen in Figure 1, and their reverberation times are set to be different, from dead to live respectively, and expected to be around 0.6 s, 0,8 and 1.0 s as a result of simulation studies. Room setting 1 (RS1), the dead setting, has carpet floor finishing with 23 absorbent panels along with some furniture and a piano. Room setting 2 (RS2), the midway setting, has parquet flooring with the same number and distribution of absorbent panels. As for room setting 3 (RS3), from sidewalls, 7 absorbent panels have been homogeneously removed and set to be transversal. Rear wall, however, was left to be absorbent. This way, amount of absorption was reduced as flutter echoes between parallel walls were prevented.

These RT settings are determined as most of the standards indicate that on the related meter-square, the optimum RT should be around 0.6 s, [13, 14, 15, 16, 17]. On the other hand, considering Beranek's formula [18],

$$\text{Optimum RT} = 0.55 \text{ x} \log(\text{V}) - 0.14, \quad (1)$$

it should be around 1.0 s *(cal.value=1,0108)*, Accordingly, creating an additional room setting with a midway RT could make it a comparable case. Each room setting was modelled using Timbre SketchUp 2014 and carried out to ODEON Room Acoustics Software, version 8.5. 3D drawings and room plan with sound source are shown in Figure 2. The point source was arranged to be 1.5 m from the ground and placed in the middle, as seen in Figure 3.

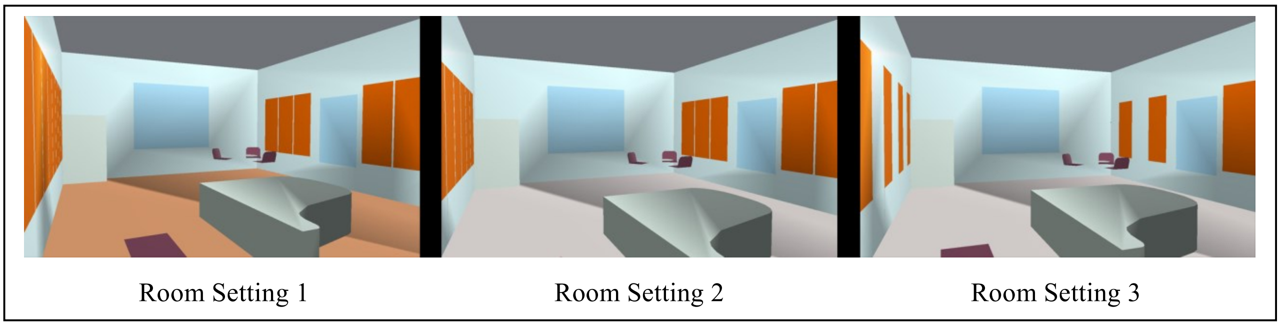


Figure 2. 3D Odeon models of three different room settings

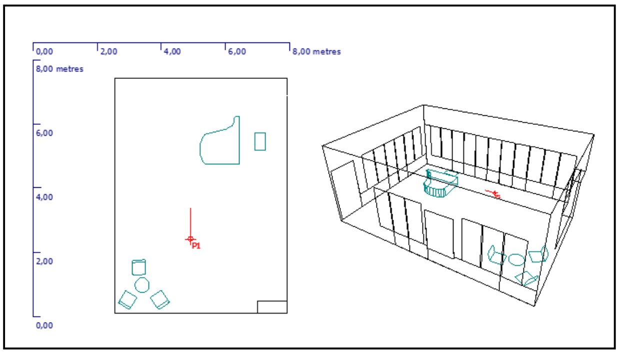


Figure 3. The position of participant as a sound source in Odeon Model

2.2. Subjective Evaluations and Open-ended Interviews

The sample group consisted of 30 classical singing trainees with an age range of 15 to 30 years; professionals *(n=8),* graduate singing students *(n=5),* undergraduate singing students *(n=6),* skilled amateurs *(n=5),* and early music education students *(n=6).*

Trainees were asked to sing as high and as low as they could in each room setting with melisma singing (singing of a single syllable of text while moving between several different notes in succession). The warm-up exercise with melisma singing was created by one of the graduate singing students from Bilkent University, Faculty of Music. The participants were also asked to sing with different singing volumes from pianissimo (softest) to fortissimo (loudest). Each session per singer was completed in around 5 minutes. Reference tones were presented by the piano shortly before producing each vocal sound. To limit the study, the position and spacing direction of participants were fixed. In order to eliminate order and learning effect, the participants sang in random rooms every other day. Therefore, preconceived opinions towards room settings were prevented considerably.

Before beginning the sessions, participants were asked to fill the first two parts of the relevant questionnaire form to collect data about their degree in music, age, and gender along with their practicing routine, concert schedule in a year, and any previous problems they had with the practice rooms. The questionnaire consisted of four parts. After each singing session, the participants were asked to fill the remaining two parts. In the last two parts, the questions were about their experiences in the practice rooms and mainly about their perceived exerted singing effort, satisfaction levels, and preferences towards rooms considering their overall experience. Subjective evaluations were also collected through open-ended comments about their experiences at the end.

While designing the questionnaire, inspiration was taken from questionnaires used in Olsson & Wahrolén's [3] and Hom's [9] studies. It was also designed using tick boxes to make it more user-friendly along with a Likert scale.

3. Results and Discussions

3.1. Acoustic Parameter Results

Reverberation times (T_{30}) for each room setting are presented in Figure 4. The materials and their absorptive areas are shown in Figure 5. As the study field is small rooms, Schroeder frequency should be emphasized. Schroeder frequency is known to be the minimum frequency limit, which is defined in metric units as [19],

$$fs = 2000\sqrt{\frac{\mathrm{T}}{\mathrm{V}}} \qquad (2)$$

where V is the volume of the room (m^3) and T is the reverberation time (s). The relevant Schroeder frequencies are shown in the Table 1. It is better to indicate bass ratio (BR) that may affect the preferences as it evokes a warmer feeling of concert hall environment. It is the ratio of reverberation time of lower frequencies (125 Hz and 250 Hz) to that of middle frequencies (500 Hz and 1 kHz) [20]. It is a major factor in judgment of acoustical quality. The BR values are also shown in Table I.

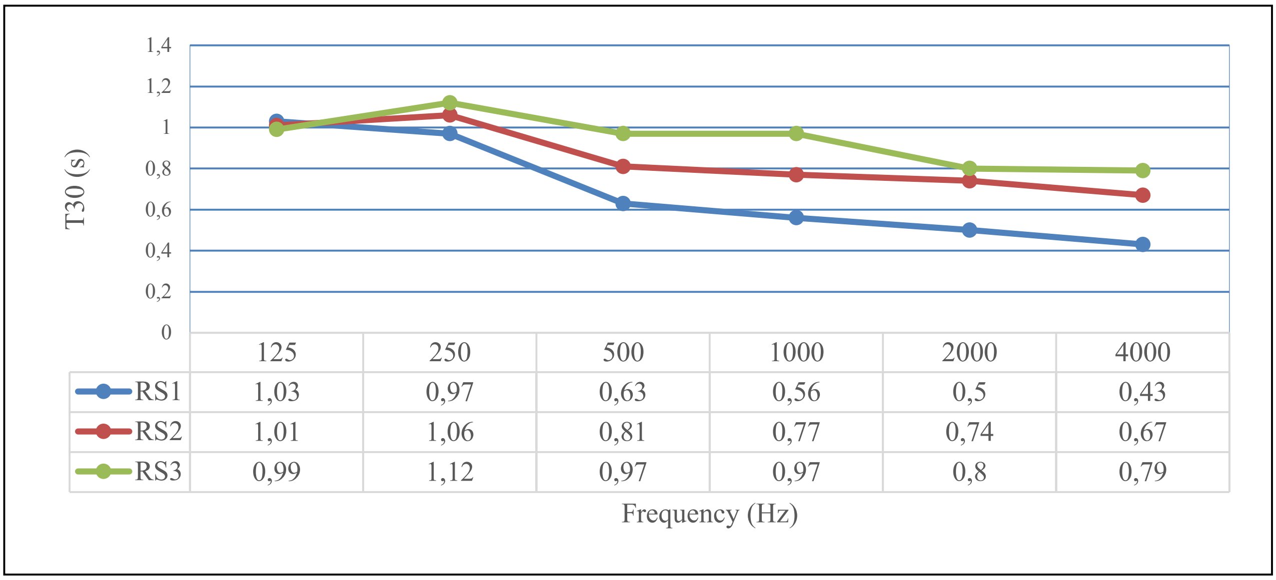


Figure 4. T_{30} for the three different practice rooms in third-octave bands

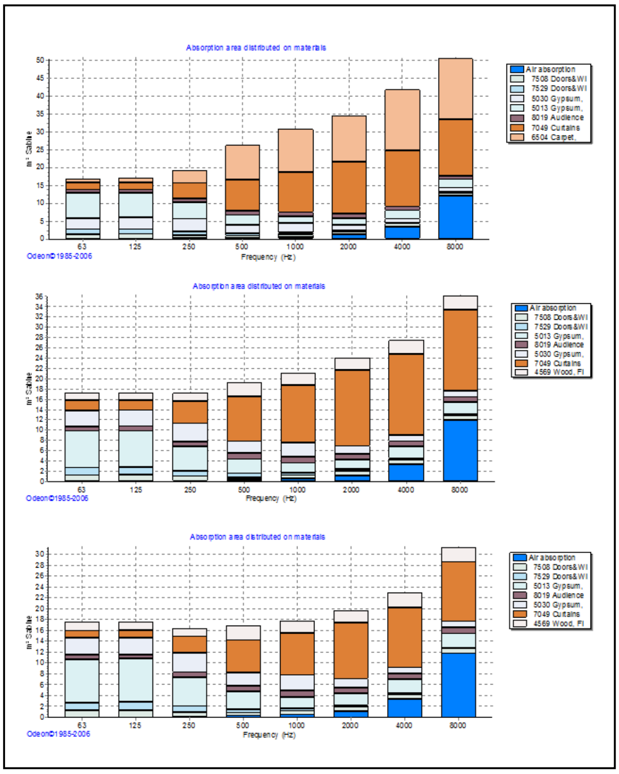


Figure 5. Room settings' absorption area distributed on materials

Table I. Schroeder frequencies and bass ratio values of the room settings

	RS1	RS2	RS3
Schroeder Frequency	136	158	176
Bass Ratio	1.68	1.31	1.08

The border frequency ranges were determined to be around 100 Hz (deep bass voice) to 1250 Hz (the peak voice of a soprano). Considering those border frequencies, the room geometry was found to be unproblematic in the case study. The practice rooms' ratio of 1:1.68:2.28 indicates that the room geometry is in the safe zone called as the Bolt-area. The Bolt-area indicates an accumulation of good room ratios. If the room ratio lies within the specified area, it means that the room has a good chance of evenly distributed modes [21]. There are some problems at frequencies from 23.6 to 47.2, which are not problematic since they are not in the target values of 100 Hz to 1250 Hz.

3.2. Subjective Evaluation Results

Data taken from 30 classical singing trainees indicated that the majority *(n=20)* of participants have suffered from vocal strain during a daily practice at some point. Besides, it appeared that the yearly concert/recital schedule of the participants *(n=18)* is heavy with at least 6 concerts/recitals in a year. For this reason, vocal strain would be a significant problem and the indoor room setting that participants practice in should not be very absorptive. Majority *(n=16)* also indicated that they spend at least 10 hours in an individual practice room for practicing per week.
Answers to questions about how they perceive their exerted singing effort in each room setting, as seen in Figure 6, showed that as RT increases, singing effort according to participants' perceptions reduces. The statistical analysis indicates that a significant correlation was found between perceived exerted

effort and preference of room setting 2 (df=29, α=0.01,p=-0.503).

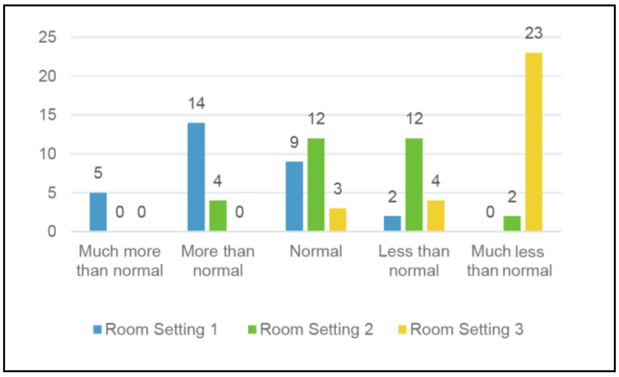


Figure 6. Perceived singing effort in room settings

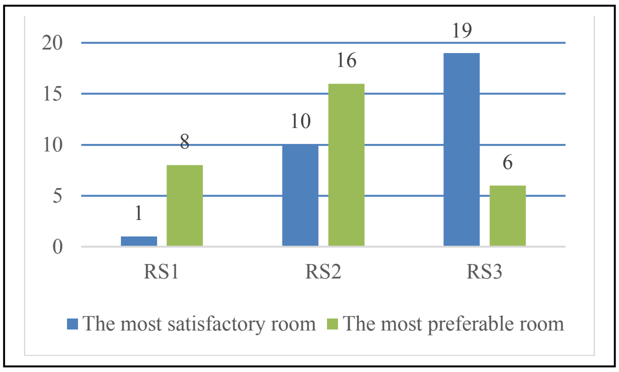


Figure 7. Distribution of the most satisfactory room vs the most preferable room

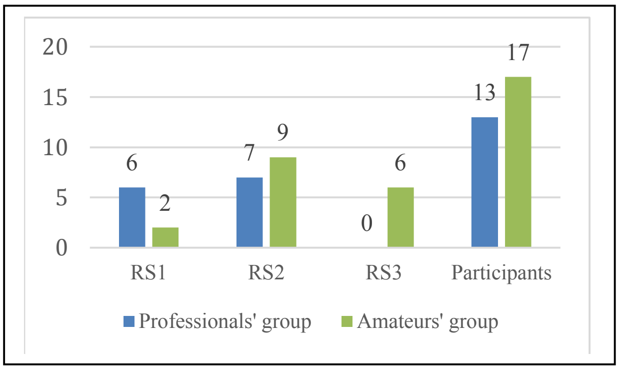


Figure 8. Distribution changes according to divided sample groups

Considering their overall experience in room settings, participants indicated that the most satisfactory room setting was RS3 (see Figure 7). However, when it comes to the answer to which room was the most preferable for practicing was RS2. It means, even though participants would like to sing in RS3, they prefer to practice in RS2. In other words, participants preferred a midway room to a live room.

Answers given in the additional comments section of the related questions indicated that participants would like to exert some singing effort to amplify their voices. According to answers of participants, their instructors, either university instructors or a singing coach, suggest that classical singing trainees should not practice in live room conditions. Otherwise, the participants would adapt to live room conditions and may have difficulties having their voices heard by the audience in concert/recitals. Therefore, it is concluded that the preference of RT in practice rooms are dependent on the perceived singing effort.
Furthermore, suggestions from instructors or coaches have a great impact on classical singing trainees. However, if the sample group is divided into two groups as amateurs (skilled amateurs, undergraduate students, early music education students) and professionals (graduate students, professionals), the results showed that there are more to analyze.
The professionals' group *(n=13)* only preferred RS1 and RS2, which means they found live room conditions not suitable for practicing. The amateurs' group *(n=17)* on the other hand, was more likely to prefer practicing in live conditions. Only 11% of them preferred practicing in a dead condition, while 35% would like to practice in the live conditions, see Figure 8.

Table II. Recommended RT values by standards

	ANSI (2002)	DfES (2002)	DfES (2003)	Wenger Corporation (2008)	ANSI (2010)
RT (s)	< 0.6	< 0.6	0.3 - 0.6	< 0.5	0.4 - 0.5

Compared to the specified standards shown in the Table II [13, 14, 15, 16, 17], the preferred practice room RT was found to be a bit higher in this study.

4. Conclusion

This study reveals that the classical singing trainees prefer absorbent conditions for practicing to amplify their voices, even though they are satisfied with hearing their voices better in live room conditions. Furthermore, the overall study shows that individual practice rooms, which have around 130 m^3 volume, require around 0.8 s reverberation, slightly later than what the standards specify.

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