Applied Acoustics 136 (2018) 132–138

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Technical note

Effects of perceived singing effort on classical singers' reverberation time preferences towards music practice rooms

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ARTICLE INFO

Keywords:
Perceived singing effort
Reverberation time
Preferences
Music practice rooms
Classical singers
Room acoustics

ABSTRACT

The purpose of this study is to investigate the effect of perceived singing effort on classical singers' reverberation time preferences in individual music practice rooms. The method has combined objective measurements (RT) and perceptual responses of participants. The participant group [N = 30] has consisted of five different backgrounds in vocal studies; early music education (EME) students, skilled amateurs, undergraduate singing students, graduate singing students, and professionals. Classical singers has been asked to sing with as high and as low as they could with melisma singing style (in opera singing technique) in three different room settings which had following reverberation times; around 0.6 s, 0.8 s, and 1.0 s. These were the values, which acoustical standards for music schools recommended. The participants have also been asked to sing with three different singing volumes in each room setting. The findings have been analysed statistically. The results showed that classical singers have preferred the room setting with 0.8 s reverberation time considering their overall experience in these room settings. Classical singers' perceived singing effort had a statistically significant relationship with preferred room setting. Furthermore, it has been found that there is a relationship between preference and background in vocal studies.

1. Introduction

Throughout the years, room acoustics regarding music was studied mainly in concert halls. The focus was on objective measurements and listeners' perceptions. However, very few studies considered musicians' perception, particularly the singer's [1]. Setting the foundation of a musical activity, music practice rooms come to the forefront. Every musician, before each concert or recital, spends a considerable amount of time practising his or her instrument. According to Lamberty, music students might spend up to 40 h per week in practice rooms [2]. Considering the time spent, these rooms require significantly more attention to indoor sound quality, nearly as much as concert halls, because these rooms are where musicians are learning and improving their skills by listening to their own instruments.

As singers are working with their own physiology instead of an extrinsic instrument, protecting their vocal instrument against damage is their upmost priority [3]. Many singers taking singing lessons are taught strictly about vocal comfort first. There are several techniques taught in singing education that focus primarily on vocal comfort in order to eliminate the vocal strain. Particularly when singing notes in higher and lower parts of their range, singers often have difficulties and if the voice is forced, *vocal folds* (sometimes misleadingly called *vocal cords*) may permanently be damaged [3]. Such problems may easily occur when practising in a room with poor acoustics. In case the room is too absorbent, then singers may force their voice to be able to properly hear themselves. Considering the time they usually spend, this may result in vocal strain and even permanent vocal damage if maintained.

Most singers are learning and improving their singing techniques in music practice rooms on their own. Learnt technique is expected to be maintained and improved throughout the development process. If incorrect technique is worked into muscle memory, it requires a lot of time and effort to correct afterwards. Therefore, poor acoustical conditions may also affect the development of basic musical skills of singing students negatively [4]. Such concerns are among the most probable reasons of having poor performances in concerts and recitals. For these reasons, the reserved rooms for singers should be efficiently and suitably designed in total absorption amount to provide for a vocal comfort zone.

Since singers in music practice rooms practice their singing voices individually, their own perceptions should be considered. Acoustical perceptions towards music practice rooms can be estimated by objective acoustical parameters. Consequently, reverberation time comes to the forefront.

Reverberation time (RT) is the primary and widely used objective

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https://doi.org/10.1016/j.apacoust.2018.02.013
Received 6 January 2016; Received in revised form 6 February 2018; Accepted 13 February 2018
Available online 03 March 2018
0003-682X/

acoustical parameter to design and evaluate room acoustics. Optimum reverberation time may differ from one singer to another. Accordingly, perceived singing effort might be a determinant factor to estimate what should be regarded as the optimum reverberation time in music practice rooms. To this date, perceived singing effort has not yet been tested in literature with classical singing trainees' RT preferences.

The aim of this study is to focus on how the perceived singing effort influences the RT preference of classical singers upon individual singing practice rooms exploring possible correlations between room conditions and singer responses. Furthermore, a potential contribution is aimed to be made to the current design standards and guidelines suggesting an optimum RT (for octave band frequencies between 250 Hz and 2000 Hz) for music practice rooms, with the differences of subjective and perceptual responses of classical singers from different backgrounds in vocal studies.

It is hypothesised that classical singers would like to exert a considerable amount of singing effort in order to amplify their voices in preparation for stage performances and thus prefer around 0.6 s (average value of octave band frequencies between 250 Hz and 2000 Hz). Additionally, strong correlations between perceived exerted singing effort and preference of RT are expected; as well as between classical singers' perceived exerted singing effort and their background in vocal studies in music. Ultimately, classical singers' background in vocal studies and preference of RT in a practice room are expected to be relate each other.

2. Method

2.1. Room settings

Two identical singing practice rooms were determined. Their plan and elevation drawings are given in Fig. 1. Their dimensions were 7.3 m ∗ 5.4 m ∗ 3.2 m (L ∗ W ∗ H) and their volumes were 128 m^3. There were absorbent panels (N = 23) with dimensions of 1.4 m ∗ 0.60 m ∗ 0.03 m (L ∗ W ∗ H) on the walls. Additionally, there was a single window of (L ∗ W) 0.9 m ∗ 1.2 m, a wooden door of (L ∗ W) 2.1 m ∗ 0.9 m, and some furniture consisting of a cabinet, table & chairs, and a piano along with a piano stool. The only difference between these two identical rooms was the floor finish material. The one had a carpeted floor while the other had parquet flooring.

At this stage, acoustical standards and design guidelines for music practice rooms were examined. According to the specified guidelines in Table 1, optimum reverberation times (RT) should be around 0.6–1.0 s range [5–7].

After measuring the present room settings, which were around 0.6 s and 0.8 s, an additional room setting was created which had RT of 1.0 s by changing the distribution and the number of absorbers on the walls of the room with RT of 0.8 s. From sidewalls, absorbent panels (N = 7) have been homogeneously removed and set to be staggered. Rear wall was left to be absorbent. Therefore, three different room settings were arranged (Fig. 2). Their RTs were set to be different, from "dead space" condition to "live space" condition respectively. Room setting 1 (RS1), the "dead" setting, had carpeted floor with 23 absorbent panels on the walls. Room setting 2 (RS2), the midway setting, had parquet flooring with the same number and distribution of absorbent panels. Lastly for room setting 3 (RS3), the "live" setting, had parquet floor with 16 absorbent panels on the walls (see Fig. 3.).

As mentioned previously, reverberation time (RT) is a primary acoustical parameter in room acoustics. However, for small volumes, it may not be the dominant criterion. Even if the correct RT for the purpose of the room is provided; lack of scattering surfaces, undesirable reflections (flutter echoes) and room resonances may pose basic acoustical problems such as loudness at particular lower frequencies [8]. In addition, depending on RT, sound levels may significantly change in small rooms. Therefore it is worth mentioning that in this study, reverberation time is only a controlling factor for perceiving singing effort rather than a subject of assessment.

Room settings were assessed to be free from flutter echoes as much as possible (in room setting 1 and 2 vertical flutter echo might still pose a risk) while keeping the current acoustical condition unchanged.

2.2. Measurements and instruments

2.2.1. Objective measurements

Room settings were evaluated in their geometry and size in order to make estimations about their modal characteristics. Since the volume of each room is adequately large, there were neither axial modes found multiple within 5%, nor tangential and oblique modes overlapped in one particular frequency. Each room setting's dimensional ratios were 1:1.68:2.28. Nearest known ratio, to indicate that the room modes are well distributed is Sepmeyer's [9], 1:1.60:2.33. Nevertheless, there were no certain criteria for the best room concerning well-distributed room modes. Accordingly, room modes were not taken into consideration in this study. Instead, Schroeder's widely used cut-off formula was used to determine the lowest frequency [10]. Relevant Schroeder Frequencies of each room setting are given in Table 2.

The position and facing direction of participants were fixed (see Fig. 1). In each room setting, reverberation time was measured according to ISO 3382-2:2008 [11] using DIRAC 3.0 Room Acoustics Software Type 7841.

2.2.2. Subjective evaluations

Thirty classical singers participated in this study. Gender distribution of the participants was as follows: 18 female, 12 male. The age range was between 15 and 30 years (M = 23.2, SD = 5.11). Participants' backgrounds in vocal studies were distributed from elementary to professional. Voices of participants were classified as bass (N = 1), baritone (N = 4), tenor (N = 5), countertenor (N = 2) contralto (N = 2), mezzo-soprano (N = 4), and soprano (N = 12). Participants were asked to perform a vocal warm-up exercise, singing from the lowest to the highest parts of their range in each room setting in melisma singing style (singing of a single syllable of text while moving between several different notes in succession) with classical singing technique. A graduate singing student from Bilkent University Faculty of Music re-composed a generic warm-up exercise which consisted of legato (joined) five notes that changed according to a reference tone. The final exercise became more complex with conjoined nine notes. The same participants were also asked to sing with different volumes from pianissimo (softest) to fortissimo (loudest). Reference tones were presented by the piano shortly before the production each vocal sound. Each session was completed in around 5 min per singer so that they could test their perceptions in the room settings better.

In order to eliminate order and learning effect, the participants were asked to perform in random rooms every other day. Therefore, preconceived opinions towards room settings were prevented considerably. All participants reported that they had been classically singing for at least 3 years and had no hearing problems.

2.2.3. Questionnaire

Subjective evaluations of participants towards each room setting were obtained through a questionnaire. Participants signed an informed consent form prior to data collection for the sake of procedure. The questionnaire was designed using tick boxes to make it more user-friendly along with a Likert scale.

The questionnaire consisted of four parts in total. In the first two parts, before their first session, participants were asked to fill the relevant questions to collect data about their background in vocal studies, age, and gender along with their practising routine, concert schedule in a year, and any previous problems they had in music practice rooms. After each singing session, participants were asked to fill the remaining two parts. In those last two parts, questions were about their experiences in practice rooms and mainly about their perceived exerted