Choir conductors: voice and acoustic environment.

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ABSTRACT
Choir conductors belong to the profession where voice is the primary working tool. Almost one-third of Latvian choir conductors participated in the study investigating a broad spectrum of voice ergonomics factors impacting conductors' vocal load. The paper will discuss one aspect extracted from the study - the relationships between conductors' voices and acoustic environments. The study consisted of three parts: an online survey, a vocal loading experiment, and interviews with conductors.

Keywords: choir conductors, vocal load, noise

1. INTRODUCTION

Choir conductors belong to professions where voice is the primary working tool; therefore, they have a high risk of acquiring voice disorders. The current studies show that a significant number of choral conductors reported laryngeal and vocal symptoms [1]. The choir conductors have specific work conditions that include rehearsals in rooms of different sizes and acoustics, singers of different numbers and ages, and work with musical material of various complexity intended for different types of voices. The conductor's voice is produced in response to a particular rehearsal condition. Vocal demand or a requirement of the vocal communication environment, vocal demand response, vocal effort, and vocal fatigue are related concepts [2]. Choir conductors' perception of the rehearsal rooms' conditions reflects the vocal effort and vocal demand response, which are directly related to vocal fatigue.

The research "An investigation of vocal load in choral conductors in the context of voice ergonomics" was carried out in 2021. Almost one-third of Latvian choir conductors participated in the study. The study investigated a broad spectrum of voice ergonomic factors impacting conductors' vocal load. The paper will discuss one particular aspect of voice ergonomics extracted from the study - the relationships between conductors' voices and acoustic environments.

2. MATERIAL AND METHODS

2.1 Study Design and Methods

The study consisted of three separate parts. The first part (Study I) included an online survey investigating choir conductors' knowledge about voice ergonomics and factors impacting voice. The one block of questions was related to noise and reverberation. Additionally, Vocal Symptom Scale (VSS), Voice Handicap Index-10 (VHI-10) and Singing Voice Handicap Index-10 (SVHI-10) were included in the questionnaire allowing to obtain information about the singers vocal health.

The second part (Study II) was organised in a group of selected choir conductors. It included a vocal loading experiment organised in rooms where each conductor usually had choir rehearsals. The study aimed to investigate vocal load expressed in time, cycle and distance doses during the vocal loading tasks. The room volume was estimated, and reverberation time (T30) was measured in unoccupied rooms using a dodecahedron loudspeaker GSR (Outline s.r.l.) as a sound source according to the ISO standard 3382-1:2009. The reverberation time was measured by a handheld acoustic analyser XL2 (NTi AUDIO) and microphone M4261 (Class 2/Type 2, sensitivity 15.2 mV/Pa). The vocal loading experiment included three tasks: vocal warm-up (with an average duration of 8.1 minutes), singing a well-known song (average duration of 26 minutes), and load reading of a neutral text (average duration of seven minutes). The average length of the experiment was 42.3 minutes (standard deviation (SD) of 1.9 minutes). The vocal loading tasks were performed under background noise conditions to simulate the natural rehearsal conditions. The piano accompaniment created the background noise during the vocal warm-up when the participant performed vocal scales. The STIPA test signal with 60 dBA@1 m was played during the singing and reading tasks. The TalkBox (NTi AUDIO) was placed where a choir would be located during rehearsal at a 1.5 m distance from the floor and a 2 m distance from the conductor. The vocal parameters (phonation time percentage ($D_{t\%}$), mean fundamental frequency (F_0), and mean sound pressure

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level (SPL)) and level of the background noise (LAF90, LA_{eq}) were obtained by calibrated voice dosimeter Vocal Holter Med (VHM) (PR. O. Voice s.r.l.). The cycle and distance doses were estimated using the algorithms developed by Švec, Popolo & Titze [3].

The third part (Study III) included a qualitative study design, and the primary data-gathering method was semi-structured interviews. This study aimed to investigate the choir conductor's unique individual experience working with the choir within the context of voice ergonomics. The interview included predetermined questions about rehearsals' room acoustic conditions. The interview was organised remotely by ZOOM. The method of thematic analysis was used for the analysis of interview content.

2.2 Participants

Study I. One hundred fifty-five choir conductors completed the online questionnaire, out of which 74.2% were female. The mean age of female respondents was 48 (SD =13.3) years and 45.5 (SD = 15.1) years for male respondents. The working experience in the choir conductor's profession was less than five years in 11% of respondents; all others were experienced conductors with a length of service from 6 to more than 40 years. Most of the conductors (72.3%) worked with mixed choirs. Fifty-seven per cent of conductors worked with two or more choirs.

Study II. Eighteen choir conductors (13 female, five male) participated in the vocal loading experiment. The mean age of female participants was 48.9 (SD = 15.8) years. Moreover, seven of the 13 participants had working experience of more than 30 years. The mean age of male participants was 46.6 (SD = 22.1) years; two of them had working experience of more than 30 years. All the participants had vocal training backgrounds and had professional education in choir conducting. In addition, they were non-smokers, and none had voice disorders in anamnesis.

Study III. Six well-known leading choir conductors were invited to take part in the interview. Besides choirs' conducting, two participants were composers and arrangers, and one of the conductors also worked with a symphonic orchestra. All of the respondents taught music in colleges and universities. The participants were males, 36-40 years old.

3. RESULTS

3.1 Study I

Fifty-two per cent of conductors identified indoor noise in rehearsal rooms. Ventilation systems, lamps and air conditioners were noise sources mentioned more often by respondents. The presence of outdoor noise (traffic, adjoining rooms, corridors) was mentioned by 62.6% of conductors.

The relationships between activity noise (AN) or choir discipline during rehearsal, vocal effort (VE), vocal fatigue (VF), and results of the self-assessment scales (VSS, VHI-10, SVHI-10) were evaluated by Spearman's Rank correlation coefficient (Table 1). Statistically significant correlation was found between indoor and outdoor noise and activity noise during rehearsals (r_S = .165, p = .04; r_S = .272, p = .001). Also, between outdoor noise and VHI-10 (r_S = .193, p = .016).

Table 1 – Relationships between activity noise, vocal effort, vocal fatigue during rehearsals and scores of Vocals Symptom Scale, Voice Handicap Index-10, and Singing Voice Handicap Index-10

Variables	AN	VE	VF	VSS	VHI
AN	1				
VE	.399**	1			
VF	.344**	.659**	1		
VSS	.254**	.458**	.506**	1	
VHI	.267**	.325**	.300**	.467**	1
SVHI	.318**	213**	.374**	.444**	.683**

** Correlation is significant at the 0.01 level (2-tailed)

3.2 Study II

The vocal loading experiment consisted of three separate tasks: vocal warm-up, singing, and loud reading. The time, cycle, and distance doses were estimated for each vocal task. Data were analysed separately in male and female participants by Paired Sample t-test and Wilcoxon Signed Rank Test.

The average $D_{t\%}$ during intensive singing was 76% in female conductors and 79% in males (Figure 1). $D_{t\%}$ was significantly higher during singing than producing warm-up scales in female and male conductors (p = .012, p = .038). Also, $D_{t\%}$ was higher during singing than reading in females and males (p < .001, p = .031).

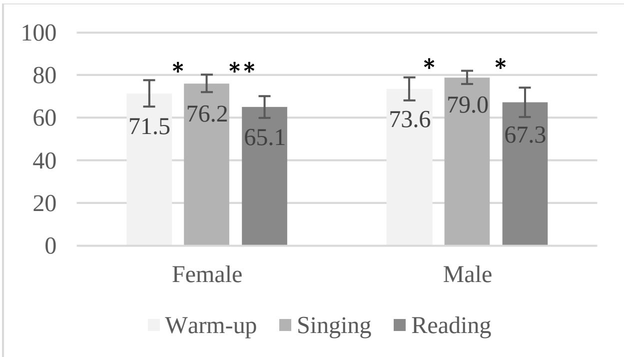

Figure 1 – $D_{t\%}$ and SD during warm-up, singing and reading in male and female participants (* significance at the 0.05 level; ** significance at the 0.01 level)

Cycle dose (D_c) quantifies the total number of oscillatory periods completed by vocal folds over time [3]. The highest average amount of kilocycles completed per minute was observed during singing tasks in female and male conductors. There were statistically significant differences between amount of D_c during singing and warm-up and reading (p = .003, p = .001) in females and in males (p = .042, p = .032) (Figure 2). There was statistically significant difference between male and female subjects in the mean D_c in warm-up scales, singing, and reading (Z = -3.205, p = .001; Z = -3.207, p = .001; Z = -2.918, p = .004, Mann-Whitney Test)

The third estimated vocal dose was a distance dose (D_d), the approximate distance tissue particles in the vocal folds travel in a cyclic trajectory over many cycles [3]. The analysis showed a statistically significant difference in D_d between singing and reading in female and male conductors (p = .001, p = .039). Vocal folds during intensive singing travelled 34 m per minute in female participants and 36.8 m per minute in male conductors (Figure 3).

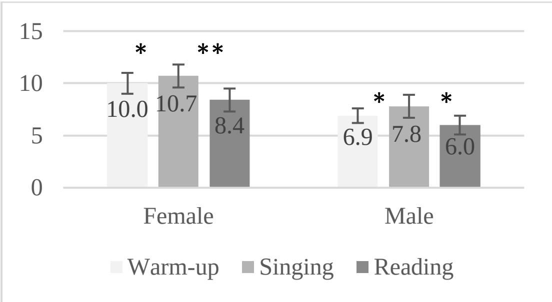

Figure 2 – Average D_c (k/cycle/min) and SD during warm-up, singing and reading in male and female participants (* significance at the 0.05 level; ** significance at the 0.01 level)

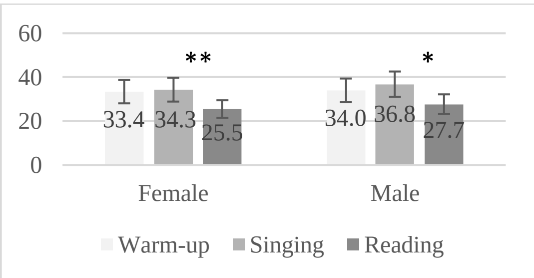

Figure 3 – Average D_d (m/min) and SD during warm-up, singing and reading in male and female participants (* significance at the 0.05 level; ** significance at the 0.01 level)

The correlation analysis did not find associations between the average amount of vocal doses during different vocal loading tasks and LA_{eq}, T30 and the volume of rehearsals rooms. However, positive strong correlation was found between background noise LAF90 and $D_{t\%}$ (r = .648, p = .017), and D_c (r = .643, p = .018) in female participants during singing task. While in males, during the singing task was observed a robust correlation between LAF90 and D_d (r = .900, p = .037). The average background noise level (LAF90) during singing task was 67.6 (SD = 2.8) dB in females and 67.8 (SD = 3.5) dB in males.

The reverberation time $RT_{0.5\text{-}1kHz}$ was measured in 21 rehearsal rooms (all experimental rooms and three rooms where worked conductors were not included in the study). There were seven small rehearsal rooms (Volume (V) = 45-200 m^3), four medium sizes (V = ≥ 200 m^3), and 10 large rehearsal rooms (V = ≥ 700 m^3). The $RT_{0.5\text{-}1\ kHz}$ only in seven of 21 measured rehearsal rooms (33.3 %) complied with the RT normative for quiet music in rehearsal rooms according to the Norwegian Standard NS 08178 [4]. Eighty per cent of large rooms, 50% of medium-sized rooms and 57% of small rooms did not meet reverberation time criteria defined in the NS 08178.

3.3 Study III

The conductors' answers during the interviews demonstrated that they were aware of interfering factors in the acoustic environment, such as indoor and outdoor noise and bad reverberation. They clearly understood the association between vocal comfort and rehearsal or performance rooms' acoustical environment. The conductors agreed that acoustics play a considerable role in choral singing. There are some quotes that conductors expressed about singing and reverberation: “the room can support singing, and the room can destroy it", and "different spaces with different reverberation times can change a choir sonority; therefore, it is a challenge for a conductor to maintain the same choral sound in acoustically different rooms”, “any room is suitable for singing and can be filled with the sound”, “it is technically hard work for conductor and singers to achieve good sonority in rooms with bad acoustics”. Conductors shared their observations that the better is room acoustics, the less vocal effort during singing is perceived to be required. They mentioned that besides reverberation time, the vocal load could depend on the size of the room, number of singers, and choir discipline during the rehearsal. The choir discipline or increased activity noise during rehearsals is crucial when working with children, especially boys' choirs.

4. DISCUSSION

The questionnaire study results showed that a noisy environment promotes increased activity noise. The activity noise creates more vocal effort and vocal fatigue and affects the conductors' voice quality. Conductors who reported a higher level of activity noise in the rehearsals had more vocal symptoms and had higher VHI-10 and SVHI-10 scores. Unfortunately, in the current literature, few studies investigate choir conductors' voices and their relations with room acoustics; therefore, comparing our results with other studies is limited. Nevertheless, our results agreed with other studies [1, 5], concluding that vocal alterations usually are consequences of excessive use of speaking and singing voices and neglecting room acoustics.

The interview data revealed the conductors' personal experience working in rehearsal rooms with different acoustics. In general, their answers reflected the data obtained by the online survey that the acoustical environment can impact vocal effort and health. The interviews provided a deeper insight into how conductors perceive the room's acoustics and their impact on the choir sound. However, the essential conclusion was that artistic ambitions and goals were priorities for conductors leaving behind the acoustical and health factors.

The non-compliance of the choir rehearsal rooms with the recommended reverberation time was an important finding in the study. Choir rehearsals usually occur in large and small halls, in large schools classrooms or in other rooms where there is space for singers and piano. The selection of rehearsal rooms often is based on the choir's financial possibilities neglecting voice ergonomics.

The study results demonstrated that singing is more vocally demanding than load reading. Statistically significant differences between these activities were observed in female and male conductors in $D_{t\%}$, D_c, and D_d. The obtained D_d during warm-up and singing for female conductors (0.56 m/s and 0.57 m/s) were close to the D_d obtained in two female graduate voice performance students with experience in teaching and opera singing during teaching classes (0.53, 0.56) [6]. In addition, we found that female conductors produced more vibratory cycles (D_c) than males, which is explained by the difference in fundamental frequency between males and females. This finding was in line with Zuim, Stewart, and Titze's study investigating vocal doses in student singers participating in musicals [7] and concludes that female conductors are at higher risk of developing voice problems due to a higher number of vibratory collisions.

We did not find the impact of rehearsal rooms' volume and reverberation time on vocal doses. However, significant associations were observed between the LAF90 in the rehearsals rooms and $D_{t\%}$, D_c, and D_d during the singing task. Unfortunately, no studies investigated relationships between acoustic parameters of spacious choir rehearsal rooms and vocal doses obtained by voice dosimetry were found. Therefore, references to studies focused on investigating the interaction between acoustics and vocal doses in other environments were made. Results regarding the impact of reverberation time on vocal doses align with Bottalico and Astolfi's study results [8]. Their study investigated vocal load in primary school teachers working in two acoustically different environments. It was observed that vocal doses and parameters did not differ between classrooms with high and low reverberation times. Similarly to our findings, Rabelo et al. found that the $D_{t\%}$ and D_c significantly increased in the background noise conditions. They investigated women between 22 and 50 years of age in a university classroom [9].

A partial discrepancy between objective and subjective measurement results was observed in the study. The questionnaire and interview results indicated the effect of reverberation and background noise on vocal effort and vocal fatigue. Therefore we expected to observe more associations between parameters of the acoustic environment and vocal doses during loading tasks. The limitation of the current study is that author did not investigate the impact of rehearsal room acoustic on voice gain and voice support which would be helpful to better understanding the relationships between the use of voice and the acoustic environment by choir conductors.

5. CONCLUSIONS

The subjective measurements confirmed that specific vocal demand conditions (high background noise in rehearsal rooms and long reverberation time) increase vocal effort and cause fatigue in choir conductors. The reverberation time in many rehearsal rooms does not meet the norms specified in the standard NS 8178: 2014. It is possible that the impact of the reverberation time on a vocal load that we did not observe during the vocal loading experiment could be more prominent if vocal dosimetry were provided during the real choir rehearsal.

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