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VOICE LEVELS IN SIMULATED ROOM ACOUSTIC ENVIRONMENTS. SEX AND AGE DIFFERENCES

Greta Öhlund Wistbacka[1,2,3*] **Franz M. Heuchel**[1] **Viveka Lyberg Åhlander**[2,4]
Birgitta Sahlén[4] **Roland Rydell**[4] **Johan Mårtensson**[4] **Jonas Brunskog**[1]

[1] Acoustic Technology, Technical University of Denmark, Denmark
[2] Speech Language Pathology, Åbo Akademi, Finland
[3] Department of Public Health and Caring Sciences, Uppsala University, Sweden
[4] Department of Logopedics, Phoniatrics and Audiology, Lund University, Sweden

ABSTRACT

Vocal problems are common among workers in voice demanding occupations. For sustaining vocal health, it is important to find efficient ways to reduce strain on the voice at work. One way to do so is optimizing the room acoustics for communication. However, we do not know enough about what kind of room acoustic conditions that support voice and speech most efficiently, and if talkers of different ages and sex have different room acoustic needs. The purpose of this project was to investigate how different acoustic environments affect voice and speech in men and women aged 20-72 (N = 80). An experimental set-up was developed for acoustic and visual simulation of different room conditions, using real-time auralization of a speaker's own voice in a 64-loudspeaker array in an anechoic room combined with virtual reality. Room conditions varied in room size, reverberation time and the speaker-oriented room acoustic parameters voice support and room gain. Preliminary results show that men adapt their voice levels more to changes in acoustic conditions compared to women. No effect of age was identified. These results show that male and female talkers respond differently to room acoustic conditions, which suggest that they might not benefit equally from room acoustic improvements.

*_**Corresponding author**: greta.ohlund.wistbacka@uu.se._

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1. INTRODUCTION

Poor room acoustic conditions has been identified as a risk factor for developing vocal problems, especially amongst workers in vocally demanding professions [1]. However, what characterizes a good room acoustics for speech is still not known in detail. The speaker's purpose is to be heard by the listener, and the speaker will therefore adapt his or her voice use to how he or she perceives him/herself to be heard in the specific environment and context [2]. The purpose of this study was to investigate how men and women aged 20-72 adapt their voice levels to different room acoustic surroundings.

2. METHOD

In this study, talkers were instructed to speak in nine simulated audio-visual room environments. The visual simulation was provided via virtual reality, and the participant was placed in rooms of different sizes with three human avatars sitting on chairs in front of the speaker's position. The acoustical simulation was provided via a real-time auralization of the reverberant sound field of the participant's voice, picked up by a head-mounted microphone, and synthesised via a 64-channel spherical loudspeaker array. The experimental set-up is described in more detail in Öhlund Wistbacka et al [3].

2.1 Participants

A total of 80 volunteers, 40 women and 40 men, in four different age groups were recruited for the study. The age groups were 20-44 years, 45-54 years, 55-64 years and 65-72 years. All participants had a better-ear hearing level of maximum 35 dB in the frequency range 250-4000Hz as measured with pure-tone audiometry. Most participants had better-ear hearing level thresholds of maximum 20 dB.

2.2 Experimental conditions

The simulated acoustic conditions varied with regards to reverberation time, speech weighted voice support [4] and room volume, see Fig. 1.

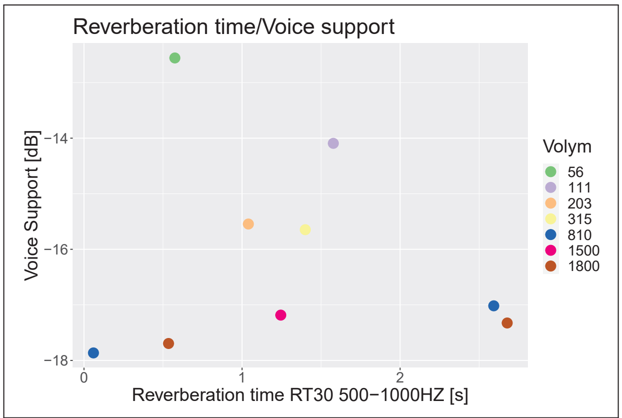

Figure 1. Reverberation time, voice support and room volumes for the experimental conditions

The room-acoustic parameter voice-support was first described by Brunskog et al. [5], and is defined as

$$ST_V = L_{E,r} - L_{E,d}, \tag{1}$$

where L_E is the total energy level, containing both the direct and the reflective parts between the mouth and the ears, $L_{E,r}$ is the reflected sound energy and $L_{E,d}$ is the energy level of the direct path between the mouth and the ears only [6].

In addition to the acoustic and visual simulations, the conditions also varied in background noise levels. One third of the tested cases contained no extra background noise, in one third a background noise level of 33 dBA pink noise was played through the loudspeaker system, and for the remaining third the noise level was 43 dBA. The order of the experimental conditions was randomized for each participant. The noise levels per tested case was also randomized, with the exception of the room with visual-simulation only, i.e. the acoustic reference room.

2.3 Analysis

The amplitude of the speech audio signals recorded via the headset as well as the measurement microphones were calibrated to sound pressure level (SPL) at 1 m distance using a recorded reference transfer-function and microphone calibrator, respectively. The effects of the different room conditions on the dependent variable voice SPL was analysed by fitting a linear mixed effect model. The lmerTest package [7] of the statistical software R [8] was used for model fitting. Since all participants were assumed to have an individual habitual voice level and range, *Participant* was considered a *random-effect*. A model was fitted with a top-down approach, including the *fixed effects* Voice support, Sex, Age and Background noise level as well as their two-way interactions. All fixed effects were analysed by their continuous scales.

3. RESULTS AND DISCUSSION

An overview of the results from the mixed linear model fitted to voice SPL is found in table Tab. 1. The final model consisted of all fixed effects as well as the interactions between voice support and sex as well as between background noise level and sex.

Table 1. Summary results of analysis of variance of the mixed model fitted to the vocal sound pressure level (SPL).

Fixed effects	F-statistic	p-value
Voice Support	$F(1, 635) = 258.2$	< 0.001
Sex	$F(1, 579) = 119.3$	< 0.001
Age	$F(1, 77) = 5.3$	0.024
Noise	$F(1, 635) = 591.5$	< 0.001
Voice support:Sex	$F(1, 635) = 122.1$	< 0.001
Sex:Noise	$F(1, 635) = 5.2$	0.023

The room effect, defined here as the change in voice level per dB change in voice support, was 0.13 dB/dB for females and 0.68 dB/dB for males. This shows that men and women adapt differently to changes in room acoustic conditions, which suggests that room acoustic improvements need to be evaluated separately for female and male talkers. The increase of voice SPL with increased voice support contradicts previous research showing the opposite relationship [5, 6, 9] and needs to be investigated further. One possible explanation could be that the audience was sitting at the same distance from the talker in all rooms, regardless of their size. This could have encouraged the talker to lower his/her voice level in the large rooms with the lowest voice support, since the audience was perceived as sitting at a close distance not requiring a voice level that would attempt to "fill the room". The rooms with higher voice support were smaller, which might have made the talker more comfortable to raise his/her voice level to be heard in the whole room.

The effect of noise on vocal SPL was 0.11 dB/dBA for females and 0.09 dB/dBA for males, showing, as expected, that both sexes increase their voice levels when background noise levels increase. The difference between the sexes is however small and possibly not clinically important. As for the effect of age on vocal SPL, the results showed an increase of 0.04 dB per year increased age. In the model, age was investigated as a continuous variable. When analysing the voice SPL on age group level (4 groups) separately, it is revealed that the youngest age group, consisting mostly of students, stands out by speaking with a lower SPL than the other three age groups. The change in voice level is therefore probably explained by some behavioural factor, such as inexperience of talking in front of an audience, and should not be interpreted as a result of biological aging. Also, no interaction effect was revealed between voice support and age, showing that age does not affect how a person adapts their voice level to this type of room acoustic change.

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