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VOCAL BEHAVIOR IN DIFFERENT ROOM ACOUSTIC CONDITIONS, NOISE, AND WITH SOUND FIELD AMPLIFICATION SYSTEM USE

Nicole Cansu[1] **Greta Öhlund Wistbacka**[2] **Sofia Holmqvist-Jämsén**[3]
Roland Rydell[4] **Viveka Lyberg Åhlander**[1,4*]
Faculty of Arts, Psychology, and Theology, Åbo Akademi University, 20500 Turku, Finland
[2] Department of Public Health and Caring Sciences; Speech-Language Pathology, Uppsala University, Uppsala SE
[3] Department of Psychology and Logopedics, University of Helsinki, Helsinki, Finland
[4]Dep of Clinical Sciences Lund, Logopedics, Phoniatrics and Audiology, Lund University, Lund, Sweden

ABSTRACT[*]

To cope with poor room acoustics in learning spaces, teachers often increase their vocal sound pressure level (SPL) to be heard in the classroom, which can lead to voice problems. While research suggests that improved acoustics may increase well-being and vocal health, little is known about its effect on vocal behavior in learning spaces. This study investigated how speakers' vocal behavior was affected by improved room acoustics, noise, and the use of a sound field amplification system (SFAS) during short speech tasks in four room acoustic conditions in a university lecture room.

The results suggested that improved room acoustics, with the addition of materials with reflective properties above the speaker position, decreased both the speakers' mean SPL and F0. A decrease in F0 and SPL was also observed as a result of SFAS use and speaking in quiet conditions compared to noise conditions. However, results indicate that the effect of room acoustics and SFAS use on vocal parameters was task dependent. Sex differences were observed in response to room acoustics and noise. Overall, the findings suggest that improved room acoustics can reduce vocal effort, but the type of task influences the relationship between vocal behavior and acoustics.

Keywords: *Vocal behavior, Vocal effort, Room acoustics*

1. INTRODUCTION

To counter the background noise and sound propagation losses in a classroom, teachers will increase their SPL [1-2]. In environments with increased vocal demands (e.g. noise, longer distance to listeners, poor acoustics) F0 also tends to rise [3]. This increase in SPL and F0 reflects a rise in vocal effort, which perceptually is characterized by an increased strain in the voice and is associated with vocal pathologies such as hyperfunctional voice disorders [4-5]. Indeed, voice disorders are two to three times more frequent among teachers compared to the general population [6].

Previously, laboratory research has been conducted to investigate the effect of room acoustics on vocal behavior [3]. While these research results are very important, one concern is the laboratory environment, which might influence vocal behavior. Additionally, studies have used different speech task types, meaning different modes of speech [3, 7-8], which might affect results. The purpose of this study was to investigate how vocal behavior, measured as changes in SPL and F0, were affected by room acoustics, noise, and SFAS use during speech tasks in a real teaching environment.

[*]*Corresponding author*: viveka.lybergahlander@abo.fi.

2. METHODS

2.1 Participants and study design

Fifteen participants (8 males, 7 females) with previous experience in public speaking (e.g., lecturing, teaching, presenting) were recruited to perform a set of three different speech tasks in front of a small audience in a university lecture room. The participants performed the speech tasks at four different time-points. In each time-point the lecture room had a different room acoustic configuration (Table 1.). Additionally, at every time-point, participants performed the speech tasks in different experimental conditions, which included the addition of non-semantic background babble noise (50 dB(A) at speaker's position) and an SFAS. The speech tasks included a describe-and-draw task of a complicated geometric figure, an approximately 3-minute-long oral presentation of a fantasy/exotic animal, and finally, a STROOP task with 40 trials. There were five to eight weeks between time points.

Table 1. Time points and corresponding acoustic configurations

Time point	Configuration
1	Baseline
2	Absorbers
3	Reflectors
4	Diffusers

2.2 Acoustic configurations

In baseline, the room included 20 mm thick fixed porous absorbers on the walls (11.5 m^2) and 40 mm thick fixed porous absorbers on the ceiling (11.5 m^2). In the absorbers configuration, baseline absorbers from walls were removed and replaced with 40 mm thick sound-absorbing wall panels on two walls (7.8 m2), and a suspended ceiling with 40 mm thick, porous absorbers were installed between ceiling beams, with two additional layers (50 + 50 mm) of low-frequency porous absorbers above the suspended ceiling. Additionally, an empty grid ceiling was installed above the speaker position. In the reflectors configuration, 3 x 8 flat gypsum panels (12.5 mm) were installed in the grid. The room was otherwise kept in the same condition as in time point 2. In the diffusers configuration, the gypsum panels were replaced by 3 x 8 wooden, vertically oriented diffusers with directional properties.

2.3 Voice recordings and statistical analysis

The speech tasks were recorded with a head-mounted microphone and analyzed using RecVox version 0.0.0.22 for Windows, freely available and downloaded from tolvan.com, which yielded phonetograms of participants' voices. Values for mean SPL and F0 were extracted from the voice recordings.

Data were analyzed using mixed effects models with vocal parameters mean SPL and F0 as outcome variables, and *fixed effects* configuration, babble noise, SFAS, age, and sex. Models with two- and three-way interactions were compared. Participant was considered a *random effect*. Models were assessed using the analysis of variance function and comparing the Akaike information criterion (AIC), so that the lower the AIC score, the better the model fit [9]. The final models included all the previously mentioned fixed effects, as well as all two-way interactions between fixed effects.

3. RESULTS AND DISCUSSION

An overview of the results of the best-fitted models for SPL and F0 in speech tasks 1 (describe-and-draw) and 2 (oral presentation) is found in Table 2, and Table 3, respectively. Our results suggest that participants decreased their mean vocal SPL by about 1.3 dB and mean F0 by about 8 Hz in the room acoustic configuration with diffusers present, compared to baseline. Speaking in the configuration with reflectors also yielded a significant F0 decrease of about 6 Hz, while the SPL decrease (1.1 dB) was ns.

Table 2. Summary results for mixed models fitted to SPL (mean) in tasks 1 and 2. RA = room acoustics.

Fixed effects	Task 1 (β, p-value)	Task 2 (β, p-value)
RA [absorbers]	-0.57, ns	-0.30, ns
RA [reflectors]	-1.08, ns	-0.43, ns
RA [diffusers]	-1.29, 0.035	-0.75, ns
Babblenoise [no]	-3.45, <0.001	-3.56, <0.001
SFAS [yes]	-1.50, 0.003	-0.62, ns

Table 3. Summary results for mixed models fitted to F0 (mean) in tasks 1 and 2. RA = room acoustics.

Fixed effects	Task 1 (β, p-value)	Task 2 (β, p-value)
RA [absorbers]	-2.34, ns	1.07, ns

RA [reflectors]	-5.58, 0.040	-2.76, ns
RA [diffusers]	-7.59, 0.007	-5.47, ns
Babblenoise [no]	-14,64, <0.001	-11.83, <0.001
SFAS [yes]	-4,90, 0.026	-0.80, ns
Babblenoise:Sex	5.45, 0.001	2.65, ns

However, significant decreases in vocal SPL and F0, interpreted as decreases in vocal effort, due to changes in the room acoustic configuration, were only observed in the describe-and-draw task, as they were non-significant for the oral presentation task. Therefore, our results suggest that the relationship between room acoustics and vocal behavior depends on the mode of speech, which is supported by previous research [10]. We observed the same discrepancy between speech tasks when investigating the effect of SFAS on vocal behavior, with SFAS decreasing vocal SPL about 1.5 dB and F0 about 5 Hz during the describe-and-draw task, but not during the oral presentation task. Noise, on the other hand, affected vocal behavior regardless of the type of speech task. Differences in cognitive demands between speech tasks may have influenced vocal behavior and the speaker's ability to utilize room acoustics and amplification for vocal adjustments. However, further research is needed to confirm this hypothesis.

Our results also suggested some interaction effects between participants' sex and background noise. These included a larger F0 change between the noise and quiet conditions for females compared to males, suggesting that females might be putting in more vocal effort when having to speak in a noisy environment. Indeed, our findings align with previous research showing that females find it more difficult to be heard in noise and report higher subjective vocal effort than males when speaking in noisy environments [11].

In summary, our results highlight that room acoustic changes with reflective materials included near the speaker decrease vocal effort. However, the relationship between vocal effort and room acoustics varies with the mode of speech, highlighting the importance of using naturalistic speech tasks that mirror real-world teaching conditions in vocal behavior studies across different acoustic environments.

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