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Teaching in a Classroom Environment: Real and Simulated Classroom Conditions and the Effects on Voice Production

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Abstract
Public school teachers have a heightened risk of voice problems. This elevated risk is caused in part by vocal demands in the workplace. Such demands can lead to changes in vocal effort. This presentation summarizes the results of several studies investigating voice use in real and simulated classroom settings. The first study used 57 teachers, who were observed for 2 weeks in teaching and nonteaching environments. Differences were identified between the two environments and across the course of the day. In the second study, how teachers adjusted their voices from one environment to the next was explored. The speech of 20 talkers was recorded in order to evaluate how vocal effort is affected by speaking style, room acoustics, and short-term vocal fatigue. The talkers read a text aloud in the presence of speech-like noise in a small classroom. A third study was conducted to investigate the effects of changes in the acoustical environment when these changes were visually concealed. In this study, 45participants were taken back and forth between two different rooms (i.e., an anechoic chamber and a variable-acoustic room) and asked to produce a short vocal task. Each time they entered the variable-acoustic room, the reverberation time and/or the background noise had been modified, while the room was kept visually the same. Generally, the results of the studies indicated that dB SPL increased in occupational versus non-occupational contexts and in the loud style relative to the normal style. Vocal behavior differences between male and female talkers were also observed.

1. Introduction

The individual and societal economic impact of voice problems experienced by teachers is significant; more than 18% of the three million school teachers in the United States miss at least one day of work per year due to voice disorders [1]. students of a teacher with a voice impairment are also less likely to learn the information taught in class [2,3]. To address the issue of lost work days and poor student learning due to teacher voice problems, previous studies have focused on understanding the causes of teachers' increased vocal risk compared to the general work force. Two frequently cited likely risk factors include (1) the need to speak loudly over long periods of time and (2) speech at an elevated speaking fundamental frequency (more vocal fold vibrations)[4]. These two are postulated to be exacerbated due to gender physiological differences since the majority of teachers are female[5] Previous work regarding teachers voice problems has included full-day ambulatory monitoring of voice use[6] , the effect of such monitoring[7], and perceptual recovery from vocal fatigue[8].

Less frequently are the effects of the communication environment[9] and goal[10], which will affect voice production and may lead to voice problems[11] as they try to maintain adequate communication. Poor room acoustics (e.g., high reverberation time, noise level both student babble and environmental noise) has also been linked to be a significant risk factor[12,13]. Classrooms are often built with speech intelligibility and speech transmission in mind. Rarely is the teacher considered, from a voice production standpoint, which may be detrimental to the teacher's voice[14].

As variations occur in communication environment or communication context, a vocalist often adjusts their vocal behavior (usually sub-consciously). These adjustments or speech accommodations may be vocally unhealthy and increase the likelihood of vocal problems. During a work day, teachers will spend some time speaking to large groups. Additionally, a teacher may speak in a range of noise levels and room reverberations. These variations may trigger speech accommodations. For example, a frequently discussed accommodation is the Lombard effect, which describes a response to increased noise: females compensating more with loudness while males with vocal pitch[15].

Many studies have considered the acoustics of a classroom yet few have considered it from the teacher's perspective[16]. Thus, to better understand the competing factors corresponding to teacher voice use in the classroom, the following research question was asked: To what degree does acoustic environment and communication goal change how a talker produces speech in the environment? Towards this end, this manuscript summarizes three studies which use real and simulated classrooms.

2. Methods

Three studies are reviewed: (1) teachers recorded for 2 weeks, comparing teaching and nonteaching environments; (2) healthy participants recorded to measure vocal effort changes due to speaking style and room acoustics; (3) healthy participants recorded to investigate effects of variations in the acoustical environment when visually concealed.

2.1. Real Classrooms: Multiday

In a cross-sectional study, teachers were observed for 2 weeks to measure their voices in a school environment versus non-school environments. The primary resource for this study was the National Center for Voice and Speech (NCVS.org) teacher voice dosimetry databank, a databank containing two-week data blocks of speaking metric that have been captured as described previously[6,17].

2.1.1. Participants

The teachers (Denver, Colorado, U.S.A.) consisted of 45f and 12m with an average age of 44 (s.d., 10) and teaching grades and topics: *Grades*: K-4th grade, 59%; 5-8th grade, 16%; and 9-12th grade, 25%; *Topics*: general classroom instruction, 71%; music or theater instruction, 16%; physical education instruction, 9%; and other 4%.

2.1.2. Instruments

Using a modified Pocket-PC and an accelerometer attached to the sterno-hyoid notch[18], voice data was calibrated for each teacher's radiated speech level[19]. The device recorded data (speaking level in dB and speaking fundamental frequency in Hz) every 30 ms, with each data record time stamped so that the record could be categorized for analysis. A complete two-weeks of data contained about 108,000 data records per hour for 18 hours per day, or 27 million records over the 2-week period.

2.1.3. Statistical analysis

Fundamental frequency and estimated dB SPL were averaged in 15-min increments and categorized into *at work* and *not at work* times: school environment (weekdays, 9am-2:30pm) and non-school environments (weekdays, 4:30pm to 10:00pm, and weekends). Treating each 15-min average as one of many samples, linear mixed-effects models (Maximum Likelihood) were implemented in R (www.r-project.org) to compare the two categories. This was done on F0 (in semitones) and dB SPL. For the teachers, usable data were from 769 days and consisted of 8451 hours.

2.2. Simulated Classroom: Style, Noise, and Reflections

In a study conducted at Michigan State University, participants were recruited to produce speech in a simulated classroom but with varied acoustics. A detailed account can be found elsewhere [20].

2.2.1. Participants

Participants (20 non-smoking college aged adults, 10m, 10f) were asked to read out-loud three standard passages at three volumes (loud, normal, soft - not a whisper) in a range of environments and noise conditions. There were 12 total reading conditions: three vocal volumes (soft, normal and loud levels), presence or absence of artificial multi-talker child babble, and presence or absence of polycarbonate panels (56 cm by 66 cm) at 1m from the participant. The classroom background noise (from the HVAC system) was 40.5 dBA. The children's babble noise was 61 dBA.

2.2.2. Instruments

The experiment took place in a small classroom (5.8m x 6m x 2.7 m), in which the floor (carpet) and ceiling (absorbent tiles) were covered by absorbent material. Babble noise was emitted by a directional speaker (Yamaha HS5), representing a common noise level generated by children engaged in quiet group work. Participants' speech was recorded by a Roland R-05 digital recorder (sampling rate of 44.1 kHz) using an omnidirectional head-mounted microphone (HMM Glottal Enterprises M-80).

2.2.3. Statistical analysis

For each condition, a time history of SPL (0.125 s intervals) was calculated from the readings (12 time histories per subject). Within-subject centering of SPL (ΔSPL) was computed from the average among all the SPL values for the subject, and this mean was subtracted from each time history value. The ΔSPL was calculated so to quantify a subject's adjustment in vocal behavior due to the different conditions. Linear mixed effects models were fit by restricted linear mixed-effects models (Maximum Likelihood) in R (www.r-project.org).

2.3. Simulated Classroom: Blinded Variations

In a third study, participants read standard texts in two different rooms: a variable acoustics room (VAC) and an anechoic chamber (Brigham Young University-Provo, Utah, U.S.A.). The purpose of this study was to test a subject's acuity and speech adjustments to undisclosed acoustic changes.

2.3.1. Participants

College student and teachers (25m, 20f) participated in a cross-sectional study. Each subject was recorded reading standard passages in the different styles in two rooms, an anechoic chamber and a VAC. The tasks were performed in each room three times, beginning with the anechoic chamber and alternating back and forth. Within the VAC, there were three acoustic configurations visually hidden from the subjects.

2.3.2. Instruments

Subjects were fitted with an accelerometer (neck-worn, Sonvox VoxLog) and a microphone (head-worn DPA 4060). In the VAC, the reverberation time (RT) was varied by adding or removing wall panels. The presence or absence of panels was not visually apparent to the participants because the wall was covered by visually opaque grill cloth.

The acoustic conditions in the VAC were designed to approximate the high and low end of ANSII standard room acoustics for elementary classrooms. The three conditions were: (VAC1) low-level brown noise with sound-absorbing panels, RT = 0.2 sec; (VAC2) low-level brown noise and without sound-absorbing panels, RT = 0.5 sec; and (VAC3) higher-level brown noise with sound-absorbing panels, RT = 0.2 sec. The low-level noise was 34 dBA while the higher level noise was 43 dBA; brown noise sounded like typical HVAC noise.

2.3.3. Statistical analysis

While several speech tasks were recorded, only the analysis of the second and third sentences of the rainbow passage was analyzed for this report. From these two sentences, several speech metrics were extracted including speech fundamental frequency, pitch strength[21], speech level (dB SPL), voice onset coefficient[22] (based on relative fundamental frequency[23]). Comparative student t-test was conducted (more sophisticated analysis is planned).

3. Results

3.1. Results Real Classrooms: Multiday

In the two-week observation study, as would be expected, teachers were significantly louder (dB SPL) at school than when outside of school times ($p<0.0001$). However, while the male teachers raised their vocal fundamental frequency when at school ($p<0.01$), the females lowered theirs ($p<0.005$). The analysis revealed another gender difference: for the males, there was no interaction of the time of day or weekday and weekend, yet for females there was significant interaction (F0, $p<0.0005$; dB SPL $p<0.0001$). This implies that in non-school environments, even after a day of work, the males behaved much the same in both weekdays and weekends, seemingly contradicting previous laboratory studies[15]. These findings may have implications on gender vocal health disparities[5].

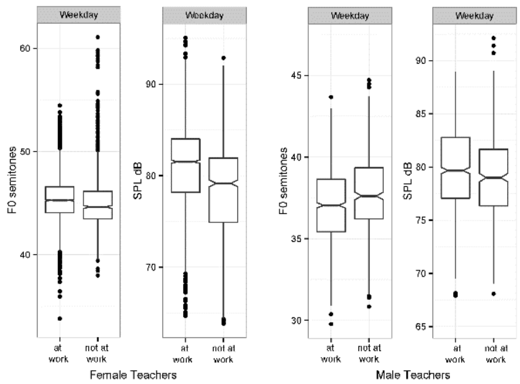

Fig. 1. Box plots for the female (left) and male (right) teachers for times between 9am-2:30pm (at work) and 4:30pm to 10:00pm (not at work).

3.2. Results Simulated Classroom: Style, Noise, and Reflections

For the study in the small classroom with varied vocal effort, noise levels and reflection panel, ΔSPL were calculated. As expected, results showed that the vocal level for the normal speaking style was higher (8.2 ΔSPL) than that of the soft speaking style (SE=0.11, $p<0.0001$), with the loud speaking style was 15.8 ΔSPL higher (SE=0.11, $p<0.0001$). The difference between soft and normal and between normal and loud was 7.7 and 6.9 ΔSPL, respectively. The estimate for the background noise was 6 ΔSPL lower than that of the babble (p<0.0001). Finally, as seen in Figure 2, the effect of the panels was a slight lowering of ΔSPL when compared to the no panel room (p<0.01).

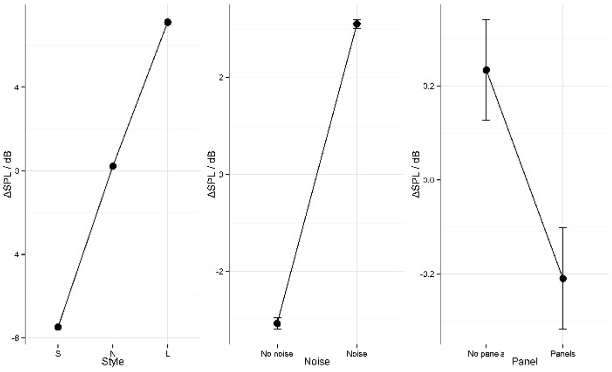

Fig. 2. Variation in ΔSPL for the conditions of speech style (left), noise (middle), and presence of panel (right). Error bars represent confidence intervals (after Bottalico, Graetzer, and Hunter, 2015).

Not surprisingly, there were elevated speech levels with noise yet there was a tendency for subjects to decrease their speech level when panels are present. These results imply that even while keeping reverberation time the same, reflective surfaces could be used by teachers in classrooms to decrease their voice level by increasing early reflections.

3.3. Results Simulated Classroom: Blinded Variations

For the study of varying acoustics in a visually similar room, subjects were asked if they thought something had changed as they moved between rooms. Nearly half indicated that they could perceive that the changes occurred to the rooms. However, half of those who indicated noticing a change upon returning to a room indicated that the change occurred in the anechoic chamber environment, which did not change. Objectively, to help validate this response, the variation of the speech metrics used in the analysis between the three different recordings in the anechoic chamber were observed with no significant differences across the three recordings. Thus, fatigue or familiarity with the speech tasks were not factors. Subjects were generally unaware to VAC changed.

For the second condition in the variable acoustics chamber (VAC2: low noise, higher reverberation), participants had a slightly higher speech fundamental frequency when compared to the lower reverberant case (VAC1, VAC3, RT=0.2 sec). Not surprisingly, the average subject didn't change their sound level (SPL) between the two noise levels. Generally, pitch strength decreased in the higher reverberant environment (low noise). Since pitch strength has been shown to have a strong correlation with perceptual judgments of voice quality, we may infer that the reverberant condition correlates with a lower voice quality.

There were gender differences in some of the speech metrics in response to the rooms. Change in pitch strength from VAC1 (low noise, low reverberation) and the other two conditions was shown to be significantly affected by gender. After accounting for room condition and reports of dehydration, females had a greater decrease than males in pitch strength (p = 0.0013). In other words, as noise or reverberation increased, females had a decrease in pitch saliency and potentially a decrease in voice quality. In VAC1 the onset coefficient for males and females were similar. However, in response to noise and reverberation females changed their onset more. In fact, males increased slightly while females decreased more substantially (Figure 3). The onset coefficient should correlate with more vocal effort.

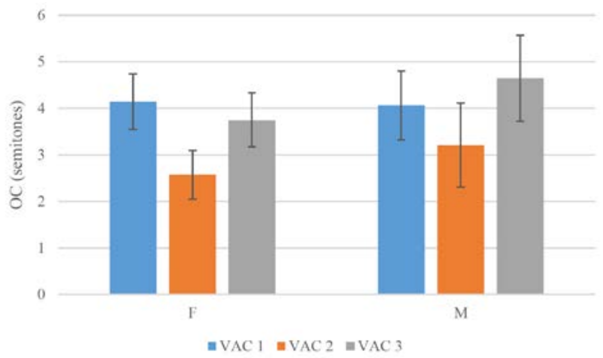

Fig. 3. Mean onset coefficient for females (F) and males (M) in the three variable acoustic conditions (after Berardi, 2015).

4. Conclusions

With the elevated voice risk of occupations like school teachers, understanding the occupational environment and the vocal health risk factors has been a growing health interest. Fundamental to that interest is understanding the effect of the design of a classroom on the teacher. The studies reviewed here add additional insight on how talkers adjust their speech to the acoustic communication environment around them, whether completely conscious of the changes or not. The results are not only relevant to better understanding classroom design but also to understanding what could be risk factors to vocal health for people who use their voice as a tool of the trade, like school teachers.

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