Talking, Teaching, and Listening: Gender differences in teachers' responses to acoustic environments

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Summary
School teachers have an elevated risk of voice problems due to the vocal demands in the workplace. Studies suggest that male and female teachers respond differently, which may explain why female teachers have an elevated risk for vocal disorders. Presented will be an amalgamation of two studies investigating gender differences in voice use in the school setting. In the first study, 57 teachers (45 f, 12 m) were observed for 2 weeks (waking hours) to compare how their voice was used at work versus not-at-work. The results suggest that female adjust more to their environment than males. In a second study, 45 participants (20 f, 25 m) performed a short vocal task in two different rooms, a variable acoustic room and an anechoic chamber. Subjects were taken back and forth between the two rooms using a deception protocol. Each time they entered the variable acoustics room, the room characteristics had been changed using two background noise conditions and two reverberation conditions. In this latter study, subjects responded to questions about their comfort and perception of changes in the acoustic environment. Objective acoustic metrics were compared to subjective perception of a room, as well as to metrics calculated from their vocal output. Several significant differences between male and females subjects were found. Most of the differences held for each room condition (at-school vs. not-at-school, varying reverberation times, varying noise levels, and levels of early reflections).

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1. Introduction[1]

More than 18% of the 3 million primary and secondary school teachers in the US miss at least 1 day of work per year due to voice disorders [1]. Further, 57.7% of school teachers but only 28.8% of non-teachers reported experiencing voice problems during their lifetimes; 11% of the teachers and just 6.2% of the non-teachers reported current voice problems [1]. The individual and societal economic impact of voice problems experienced by teachers is significant; for example, teachers comprise only 4.2% of the U.S. workforce and 16% of the population of professional voice users. To further the significance of the elevated vocal risk of teachers, consider that teachers are more than twice as likely to be female and females have a higher propensity than males for prolonged voice problems [1,2]. These voice problems affect not only the teachers, but several studies suggest that students with a teacher with a voice impairment are less likely to learn the information taught in class [3,4]. Thus, addressing the causes of teachers' increased vocal risk that teachers would have significant impact on education.

A primary cause of teachers' vocal health issues is the high vocal demands placed on them—speaking for extended periods of times at a loud volume and often at a higher fundamental frequency. It is also likely that characteristics of the classroom environment may play a part as well: allergens or other airborne particulates; humidity level; noise level (both student babble and environmental noise); and poor acoustics (e.g. high reverberation time, or extra low reverberation time) [5]. Speakers adjust their vocal behaviors (often sub-consciously) to these types of environmental variations, as well as to communication context. These adjustments, called speech accommodations or strategies [6,7], are often unhealthy and, therefore, may increase the risk of vocal health problems. Within a classroom, several factors may prompt such accommodations; among these factors are changes in: (1) the acoustic environment, such as variance in noise and room reverberation; and (2) perceived audience/listener requirements. Unhealthy accommodations also appear to occur with vocal loading (e.g., excessive voice use). For example, the speech F0 usually drifts upward with prolonged speaking [8,9]. Other studies suggest that prolonged speaking causes more frequent glottal hyperfunction response in talkers and is a risk for voice disorders [10]. Further, research shows that talkers adjust their speech production to accommodate their perceived audience like a class of older compared to younger children [11,12]. Clear Speech is an accommodation that is adopted when speakers are told that their communication partner has a hearing loss; the resulting produced speech is more intelligible than everyday conversational speech and improves listening in nearly every communication environment [13,14].

While many studies have considered the acoustics of communication environments, fewer have studied it from the perspective of the talker. Additionally, fewer still have looked at gender specific talker accommodations to those environments. Thus, the current studies examine the following research questions: To what degree does acoustic environment and communication goal of the environment change how a talker produces speech in the environment? And How do these changes differ between males and females? To answer these questions, this manuscript presents two ongoing studies, both contributing insight into different aspects of these questions.

2. Methods

Two studies are presented below. The first involves a multi-day examination of teachers' voice use, along with their adjustment to two general situations (at-work and not-at-work), giving a broad look at the research question. The second study is a narrower look at the research question with an experiment investigating how speech production changes due to reverberation and noise in a laboratory setting.

1.1. Multi-day observation of teachers

1.1.1. Methods

In the first study, data was collected from 57 teachers were observed for 2 weeks (waking hours) in order to compare how their voices changed in school environment (mostly classroom) versus non-school environments (everything else). The primary resource for this study was the National Center for Voice and Speech teacher voice dosimetry databank, a databank containing two-week data blocks that were captured of teachers voice as described previously [9,10]. A short summary of the acquisition methods will be presented here for completeness.

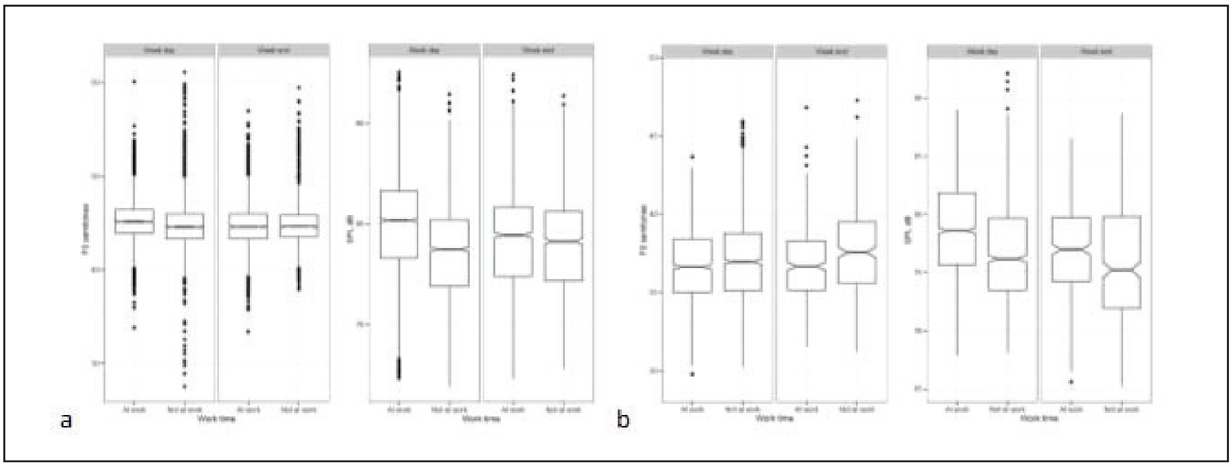

Fig. 1. Notched box plots for the male teachers (a) and female teachers (b) showing compiled a weekday and weekend for times between 9am-2:30pm (at-work) and 4:30pm to 10:00pm (not-at-work).

Forty-five female and twelve male teachers participated in this study, with an average age of 44 (median, 55; s.d., 10). All teachers were from more than a dozen schools in the Denver metropolitan area (Colorado, U.S.A). Teacher breakdown by topic was: general classroom instruction, 71%; music/theater instruction, 16%; physical education instruction, 9%; and other (e.g., library instruction, special education), 4%. The subject breakdown by teaching grade was: K-4th grade, 59%; 5-8th grade, 16%; and 9-12th grade, 25%. Voice dosimeter data were calibrated for each teacher's voice level [15,16]. Each teacher was taught how to attach and use the dosimeter, although a laboratory technician was on call at all hours to provide technical support. Among other speech metrics, the device recorded a person's voice level (dB) and speech fundamental frequency (F0) every 30 ms, with each data record time stamped so that the record could be searched by date and time for analysis. Because each voice dosimeter was individually setup for a specific teacher, data files were also categorized by dosimeter using a unique identification number. For a teacher who completed the two-week observation with the voice dosimeter, the complete data record contained approximately 108,000 data points per hour and nearly 2 million records per day (assuming 18 hours). For a 14-day period, that would be approximately 27 million time stamped data records.

Data were compiled first into at-work and not-at-work based on the time of day: at-work (weekdays, 9am-2:30pm) and not-at-work (weekdays, 4:30pm to 10:00pm, and weekends). Analysis scripts were written (MATLAB) that could search all of the voice dosimeter data by gender, date and time. Using these scripts, average voicing measures were calculated in 15-minute increments throughout all the days. If there was at least 30 seconds of voicing within a 15-minute increment, the data were utilized for further statistical analysis. From these 15-minute increment averages, treating each increment as one of many voice samples from a subject, linear mixed-effects models (fit by Maximum Likelihood) were implemented using R (www.r-project.org, ver 3.1.2, lme4). These were used to compare the at-work versus not-at-work values for both weekdays and weekends. For these analysis, gender was tracked to see if there was an interaction to note. This analysis was conducted on F0 (in semitones), log(F0 in Hz) and dB; semitones and log(F0). Semitones and log(F0) were used so that F0 values in the long recording had a more normal distribution. Data from the 45 female and 12 male teachers consisted of 769 days of 798 possible days of observation; and usable voice data consisted of 8451 hours, more than 6100 hrs from the weekdays and 2345 hrs from the weekend. Unusable data resulted from teachers temporarily taking off the device, or from temporary equipment malfunction (e.g., electrical short, software failure).

1.1.2. Results

Male and female teachers appeared to treat the two environments differently. Figure 1 shows the averages of F0 (in semitones) and dB, divided into at-work and not-at-work environments, with female teachers on the right and males on the left. For the female subjects, F0 was significantly lower for not-at-work times (log(F0) was $p<0.05$, F0 in semitones was $p<0.005$) compared to at-work times. Not surprisingly, the difference between voicing produced in weekday and weekend not-at-work times (during the same hours of the day) was not significant since those times would likely be similar. In the female teachers, larger effects were shown in terms of the dB values, with the not-at-work weekday and weekend values significantly lower than the at-work values ($p<0.0001$). As a female teacher was in the classroom, they spoke louder and with a higher pitch than when they were not in the classroom.

The males teachers also showed a significant difference for at-work values compared to not-at-work values for dB changes ($p<0.0001$). However, whereas female teachers lowered their F0 during not-at-work times, the males raised their vocal pitch (log(F0) was $p<0.0001$, F0 in semitones was $p<0.01$).

The statistical models also reveals another gender difference. For the males, there was no interaction (a statistical term resulting from the statistical model) of the time of day or weekday and weekend, while for females there was significant interaction ($p<0.05$, $p<0.0005$, and $p<0.0001$ for log(F0), F0 in semitones, and dB respectively). This implies that in the evening, even after a day of work, the males behaved much the same in both weekdays and weekends, which does not support previous laboratory studies [17].

1.2. Variable Acoustics: Blinded

1.2.1. Methods

In a second study, 45 participants (25 m, 20 f) performed a short vocal task in two different rooms: a variable acoustic room and an anechoic chamber (Brigham Young University-Provo, Utah, U.S.A.). Participants were equipped with a head-worn microphone and a neck-worn accelerometer. Subjects were instructed on proper speech elicitation protocol for the study: e.g. using conversational voice, repeating mistaken speech tasks. Each subject was taken to the anechoic chamber and told that the study was intended to investigate how speech would change as a result of the unusual acoustical environment in the anechoic chamber. Nevertheless, the real goal was to test gender differences in acuity to undisclosed changes in a variable acoustic chamber (the deception protocol was conducted after approval of the local Institutional Review Board).

Undisclosed to the participants, three acoustical conditions were employed in the second room, a variable acoustics chamber (Figure 2). These conditions were: (1) low-level brown noise (sounding much like a common HVAC system) with many sound-absorbing panels, (2) higher-level brown noise with many sound-absorbing panels, and (3) low-level brown noise with few sound-absorbing panels. The low-level noise at the talker position was approximately 35 dBA, whereas the higher-level noise was approximately 50 dBA. With many absorption panels in place, the room reverberation time was approximately 0.2 seconds. With few panels in place, reverberation time increased to approximately 0.5 seconds. The presence or absence of panels was not visually apparent to the participants because the potential panel positions were masked by visually opaque grill cloth (not shown in the figure). The verification of the room was conducted according to ISO 3382-2 for survey accuracy. The impulse response was measured using two 1/2” microphones and a dodecahedron loudspeaker.

Figure 2. Variable Acoustics Chamber without visually opaque grill cloth showing two reverberation conditions. Upper, low reverberation condition at 0.2 sec; Lower, medium reverberation at 0.5 sec.

Each subject was first recorded in the anechoic chamber, then in the variable acoustics chamber. Each time they entered the variable acoustics chamber, the acoustics of the room had changed randomly through the conditions mentioned. The lab technician escorted the subject from one room to the next, having the subject perform the speech task in each room. This process was repeated for a total of six recordings (three in the anechoic chamber and three in the variable acoustics chamber) so that each variable acoustics chamber permutation was included in the recording sequence.

While several speech tasks were recorded, only the analysis of the second and third sentences of the rainbow passage are presented here. Further analysis is currently underway.

1.2.2. Results

To help validate the analysis, the variation of the speech metrics used in the analysis between the three different recordings in the anechoic chamber were observed. There were no significant changes across these three different recordings. This implies that fatigue or familiarity with the speech tasks were not factors.

For the third room condition (low noise, higher reverberation) in the variable acoustics chamber, participants had a higher fundamental frequency (1.87 Hz) when compared to the lower reverberant case (0.2 sec). For the average subject, they did not change their sound level between the two cases. However, for subjects with questionnaire reports of dehydration, they did have a significant change in dB (0.61 dB, p 0.026) for changes in reverberation. Using a measure of pitch strength [18] (pitch saliency), after accounting for general gender differences, pitch strength in the higher reverberant environment (low noise) was lower. Since pitch strength has been shown to have a strong correlation with perceptual judgments of voice quality [19], we may infer that the reverberant condition correlates with a lower voice quality.

There were gender differences in response to the rooms. Change in pitch strength from the first room condition (low noise, low reverberation) and the other two conditions (high noise, low reverberation; and low noise, high reverberation) was shown to be significantly affected by gender, room, and whether the participant reported feeling dehydrated. 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 in voice quality.

3. Conclusions

With the elevated voice risk of some occupations like school teachers, an understanding of the occupational environment, as well as of the vocal health risk factors of the environment, becomes increasingly important. Fundamental to this understanding is to determine if and to what degree gender differences impact the effect of a room on a talker. These results are not only relevant to room design but also to understanding talkers' acuity to acoustic conditions and their adjustments to them.

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