

VOICE USE AMONG MUSIC THEORY TEACHERS: A VOICE DOSIMETRY AND SELF-ASSESSMENT STUDY

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KEYWORDS: Vocal loading-Voice accumulation-Occupational voice-Background noise-Lombard effect.

ABSTRACT

Summary: Objectives. This study aimed (1) to investigate music theory teachers' professional and extra-professional vocal loading and background noise exposure, (2) to determine the correlation between vocal loading and background noise, and (3) to determine the correlation between vocal loading and self-evaluation data. **Methods.** Using voice dosimetry, 13 music theory teachers were monitored for one workweek. The parameters analyzed were voice sound pressure level (SPL), fundamental frequency (Fo), phonation time, vocal loading index (VLI), and noise SPL. Spearman correlation was used to correlate vocal loading parameters (voice SPL, Fo, and phonation time) and noise SPL. Each day, the subjects self-assessed their voice using visual analog scales. VLI and self-evaluation data were correlated using Spearman correlation.

Results. Vocal loading parameters and noise SPL were significantly higher in the professional than in the extra-professional environment. Voice SPL, phonation time, and female subjects' Fo correlated positively with noise SPL. VLI correlated with self-assessed voice quality, vocal fatigue, and amount of singing and speaking voice produced. **Conclusions.** Teaching music theory is a profession with high vocal demands. More background noise is associated with increased vocal loading and may indirectly increase the risk for voice disorders. Correlations between VLI and self-assessments suggest that these teachers are well aware of their vocal demands and feel their effect on voice quality and vocal fatigue. Visual analog scales seem to represent a useful tool for subjective vocal loading assessment and associated symptoms in these professional voice users.

INTRODUCTION

Teachers rely on their voice as a primary tool for work and are therefore recognized as professional voice users.¹ Like other professional voice users, such as singers or call center agents, teachers face an increased risk of encountering voice problems.^{2,3} Roy et al.⁴ found that teachers develop voice disorders at almost twice the rate of the general population. Music and singing teachers are even more at risk.⁵⁻⁷ Unlike classroom teachers, they not only use their voice to transmit the subject matter and manage the classroom but also use it as an instrument when singing with their students. In Belgium, certain music teachers are referred to as music theory teachers. Music theory teachers teach theoretical knowledge and practical musical skills such as reading and writing scores, as well as musical perception and production (pitch accuracy and singing in harmony), to groups of individuals who learn music during their free time. Employed at music schools, named *académies de musique* or *conservatoires de musique*, they often teach singing or playing an instrument. As they use both their speaking and singing voice at work, music theory teachers are assumed to experience extended voice use.

The increased risk for voice disorders among teachers in general, and among music or singing teachers in particular, has repeatedly been associated with the high vocal demands linked to their profession.^{4,5,8-10} Vocal loading is a term that denotes the quantity of vocal demands placed on the phonatory system.¹⁰ It is thought to be mostly determined by voice sound pressure level (SPL), fundamental frequency (Fo), and phonation time.¹¹ Titze et al.¹²⁻¹⁴ introduced five vocal doses to determine the impact of repeated vocal fold vibrations on the exposed tissue over some selected durations of measurement: time dose (ie, total phonation time), cycle dose (ie, total vocal fold vibration cycle), distance dose (ie, total distance covered by the vocal folds), energy dissipation dose (ie, total amount of heat created by the vocal folds), and radiated energy dose (ie, total energy emitted by the mouth). Rantala and Vilkmán¹⁵ had previously described cycle dose as the vocal loading index (VLI); it depends crucially on phonation time and voice Fo. Finally, background noise level may also influence vocal loading, as it automatically causes speakers to increase their voice SPL and Fo or modulate spectral aspects.^{16,17} Studying all of these parameters is important in defining and interpreting the vocal profiles of teachers and other professional voice users. Large quantities of data, collected in ecological context, are needed to determine what constitutes a normal amount versus excess vocal loading.

Voice dosimetry or voice accumulation allows researchers to establish such corpora of voice use data. Voice dosimeters are portable devices that can be used to monitor a person's vocal behavior in real-life situations and over extended periods of time, for example, during the course of a normal workday. This method of collecting data allows one to present an authentic picture of both professional and extra-professional vocal demands. Voice accumulation research on teachers' voices has led to three important findings, which provide the background for this study: (1) Vocal loading is higher in teachers than in the general population¹⁸; (2) teachers' vocal loading is higher at work than during their free time^{11,19-21}; and (3) certain subgroups of teachers show different vocal loading patterns.^{10,11} Music teachers, in particular, must cope with much higher vocal loading than regular schoolteachers.¹⁰ To date, the specific population of music theory teachers has not been investigated.

Although objectivity is one of the decisive advantages of voice accumulation, the consultation of subjective data as well may be important to interpret vocal loading measurements. Rantala and Vilkmán¹⁵ found that objective values for teachers' vocal loading are reflected in how these teachers self-assess their voice. In their study, 12 female teachers were instructed to answer a questionnaire about subjective voice complaints and recordings were made of their professional voice use. The voice recordings were then used to calculate the VLI. A higher VLI was associated with a higher number of subjective voice complaints. A more recent study on 28 teachers' vocal loading supports this finding: Measured cycle dose (i.e., VLI) was significantly higher in female teachers with self-reported voice complaints than in those without voice complaints.²² Comparing VLI

measures with self-assessment measures may therefore help us understand the relationship between phonatory behavior and the development of voice disorders.

The present paper describes vocal loading parameters and background noise levels experienced by 13 music theory teachers as measured with voice dosimetry. Our aims were (1) to describe music theory teachers' vocal loading and their exposure to background noise as a function of context (professional versus extra-professional); (2) to determine the relationship between background noise level and the three vocal loading parameters: voice SPL, voice F_0 , and phonation time; and (3) to examine whether the VLI is reflected in subjects' self-perception of their voice.

TABLE 1. Personal Information on Each Subject

	Teaching	Teaching time	Total duration of	Duration of voice	Duration of voice	
	Age	experience	per week	voice monitoring	monitoring at work	monitoring off-work
Subjects	(years)	(years)	(hours)	(hours)	(hours)	(hours)
F1	29	8	18	74	26	48
F2	38	10	20	53	26	27
F3	58	36	24	99	24	75
F4	49	23	21	77	13	64
F5	39	16	24	39	15	24
F6	26	3	20	51	17	34
F7	46	22	12	74	21	53
F8	47	23	17	44	19	25
F9	50	26	18	63	26	37
M1	52	26	24	72	17	55
M2	29	5	24	68	26	42
M3	49	30	11	62	29	33
M4	27	2	11	82	24	58

Note: Female subjects are labeled with the letter F (i.e., F1-F9) and male subjects with M (i.e., M1-M4).

METHODS

SUBJECTS

Thirteen music theory teachers (9 females and 4 males) from the French-speaking part of Belgium agreed to wear a voice dosimeter for one 6-day workweek (from Monday to Saturday). Table 1 provides individual information on each subject. The subjects' age ranged from 26 to 58 years, with a mean of 41 (standard deviation [SD] = 11). On average, subjects worked 19 hours per week (SD = 5) and had 18 years of teaching experience (SD = 11).

VOICE DOSIMETRY

A VoxLog voice dosimeter (Sonvox, Umea, Sweden) was used to measure the subjects' vocal loading over the course of the week. VoxLog voice dosimeters contain a neck collar with an integrated accelerometer and a microphone. The former measures the speaker's Fo (Hz) and phonation time (%), while the latter detects voice SPL (dB) and background noise SPL (dB). Like other voice dosimeters, the VoxLog records voice data without recording the actual speech signal and thereby protects the speaker's confidentiality.

The subjects were instructed to wear the VoxLog each day from the early morning until late evening, resulting in a mean of 44 hours (SD =16) of data recording per subject. Regarding the VoxLog settings, the time window was set to 5 seconds, meaning that data were averaged every 5 seconds. No A-weighting was applied. The feedback function was not activated. During the week of monitoring, the examiner met twice with the subjects to download and save their voice dosimetry data. VoxLog Discovery software was used to analyze phonation time, Fo, voice SPL, VLI (calculated by VoxLog Discovery), and noise SPL over the recording days based on the context. The professional context included all work activities such as teaching, lesson preparation, rehearsals, and concerts. The extra-professional context included nonwork-related activities, such as leisure and family time.

QUESTIONNAIRE

Each monitoring day, subjects answered a two-part questionnaire. The first part consisted of a timetable in which subjects could report their working hours, nonworking hours and free time activities. It allowed the partition of data into professional and extra-professional contexts. To evaluate the subjects' perception of their voice, the second part consisted of visual analog scales, which had to be completed at the end of each testing day. On scales ranging from 0 to 100 mm, subjects evaluated their perceived voice quality at the end of the day (0 = poor; 100 = excellent), vocal fatigue (0 = no fatigue; 100 = extreme fatigue), the amount of speaking voice used (0 = low voice use; 100 = extensive voice use), and the amount of singing voice used (0 = low voice use; 100 = extensive voice use). Visual analog scales were chosen over numerical rating systems because they are generally easier to use when estimating the amount of voice use. Moreover, visual analog scales represent a commonly used instrument for self-rating voice complaints in professional voice users.²³⁻²⁵ Because of the continuous aspect of visual analog scales, they help detect more subtle differences than discrete scales.

TABLE 2. Average Vocal Loading Parameters and Background Noise Level According to Context and Gender

		Professional context		Extra-professional context		Global		Effect of context for the entire sample (Wilcoxon test)
		Females	Males	Females	Males	Females	Males	Entire sample
		μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	μ (SD)	Z
Voice	SPL (dB)	93(14)	90 (14)	88(14)	85(14)	91 (14)	89 (14)	-5459*
	Fo (Hz)	283 (66)	172 (52)	239 (60)	138 (37)	267 (69)	160 (51)	-6049*
	Phonation time (%)	33(5)	28(7)	10(3)	8(4)	18(4)	15(4)	-6834*
Noise	SPL (dB)	80(13)	78(13)	73(13)	74(13)	76(4)	75(6)	-5384*

* $p \leq 0.001$.

ANALYSIS AND STATISTICS

IBM SPSS statistics software (version 20) was used for statistical analysis.

Firstly, global values of the voice SPL, Fo, phonation time, and background noise level parameters were calculated for the entire sample and according to gender. For each parameter, Wilcoxon signed-rank test was performed to investigate the effect of context (professional versus extra-professional).

Secondly, correlations between vocal loading parameters (voice SPL, Fo, and phonation time) and noise SPL were analyzed by means of Spearman correlation.

Thirdly, correlations between the daily VLI and subjects' self-assessment of their voice were analyzed with Spearman correlation. Among the vocal loading parameters calculated by the VoxLog Discovery, VLI was selected for this correlation because it is the most representative measure of the actual amount of work accomplished by the vocal folds over the course of the day.

For the second and third aims, correlations were based on one data point per day for each subject, resulting in a total of 78 data points (13 teachers * 6 days).

RESULTS

VOCAL LOADING AND EXPOSURE TO BACKGROUND NOISE AS A FUNCTION OF CONTEXT

Average vocal loading and background noise values according to context and gender are presented in Table 2. Figure 1 complements this table, providing individual data. Wilcoxon test revealed that, irrespective of gender, subjects showed significantly higher vocal loading and were exposed to higher noise levels in their professional environment than during nonworking hours. What also became apparent is that females consistently exhibited higher vocal loading parameters than their male colleagues.

CORRELATIONS BETWEEN BACKGROUND NOISE AND VOCAL LOADING PARAMETERS

Spearman correlation was used to calculate whether voice SPL, Fo, and phonation time varied as a function of background noise level. Statistics revealed a significant strong positive correlation between background noise level and voice SPL for the entire sample ($r = 0.615$, $p < 0.001$), which also holds when females ($r = 0.627$, $p < 0.001$) and males ($r = 0.739$, $p < 0.001$) are considered separately.

Regarding the relation between background noise level and Fo, statistics showed a nonsignificant correlation for the entire sample ($r = 0.181$, $p = 0.118$). A moderate significant positive correlation between Fo and background noise level was measured in female subjects ($r = 0.411$, $p = 0.002$) but not in males ($r = 0.388$, $p = 0.055$).

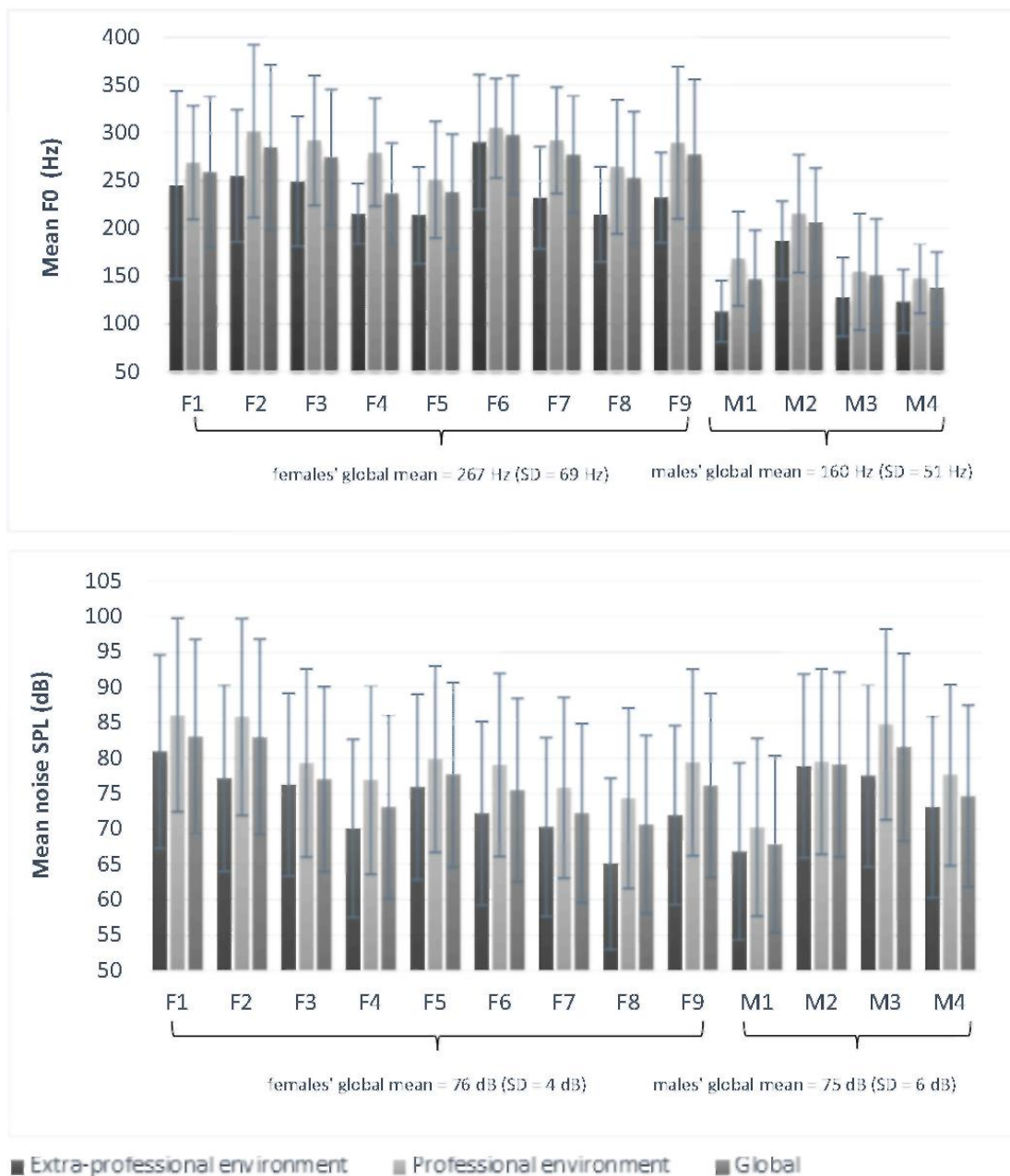
A significant strong positive correlation was also found between background noise level and phonation time ($r = 0.504$, $p < 0.001$) for the entire sample. When both genders were considered separately, the correlation was moderate for females ($r = 0.370$, $p = 0.007$) and strong for males ($r = 0.730$, $p < 0.001$).

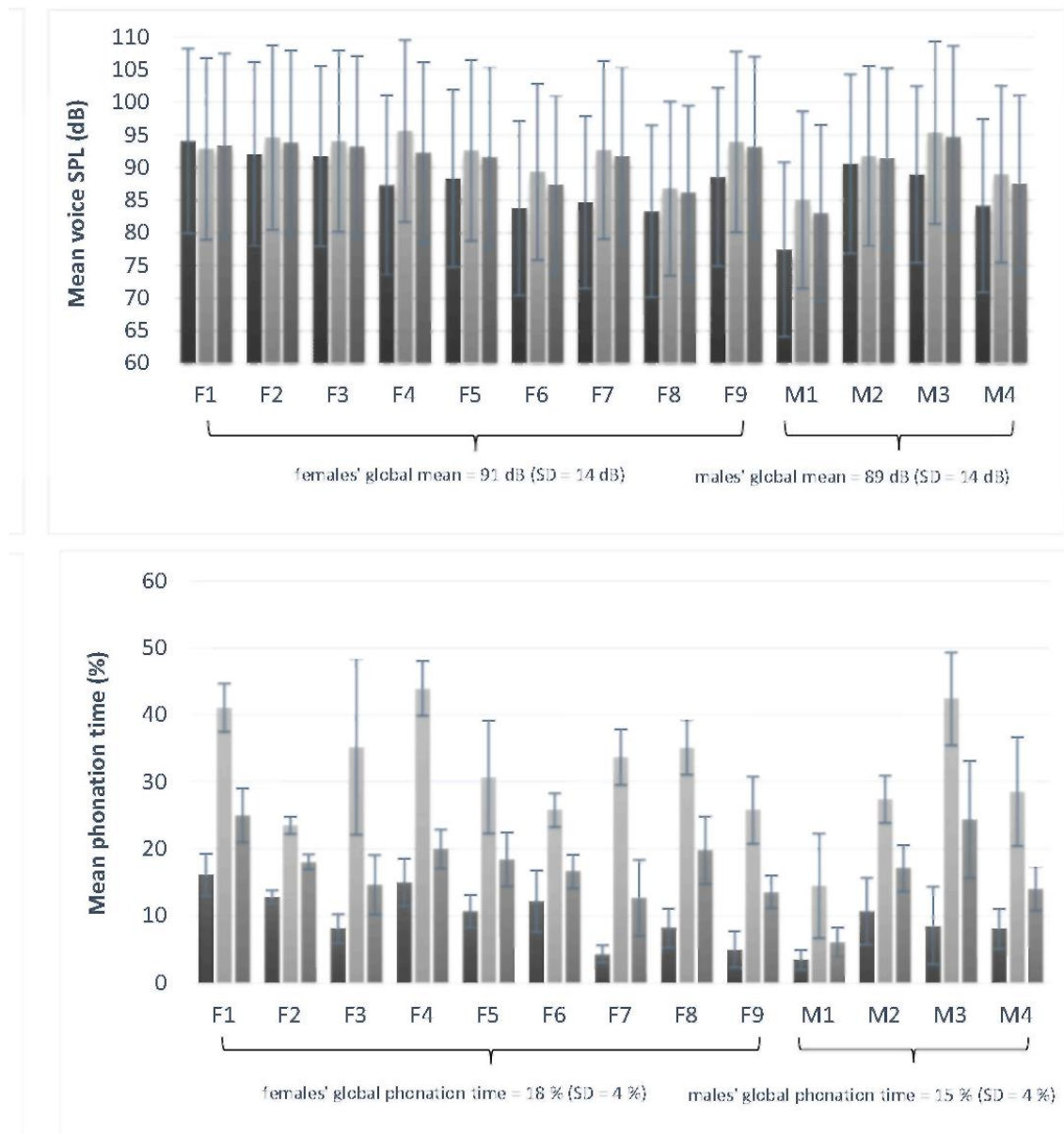
CORRELATION BETWEEN DAILY VOCAL LOADING INDEX AND SELF-ASSESSMENTS

Spearman correlation was also used to calculate whether VLI correlated with the subjects' self-assessed voice quality, vocal fatigue, and quantity of speaking and singing voice used. For the entire sample, a strong negative correlation between VLI and voice quality was measured ($r = -0.538$, $p < 0.001$). The higher the daily number of oscillations, the worse subjects considered their voice quality to be at the end of the day. This correlation was stronger in females ($r = -0.535$, $p < 0.001$) than in males ($r = -0.421$, $p = 0.036$). Irrespective of gender, the VLI also moderately and positively correlated with vocal fatigue (entire sample: $r = 0.438$, $p < 0.001$; females: $r = 0.431$, $p = 0.002$; males: $r = 0.484$, $p = 0.014$). Thus, a rise in daily VLI was accompanied by a rise in

vocal fatigue reported at the end of the day. In the entire sample and in females, VLI also correlated positively with the self-assessed quantity of speaking voice used (moderate correlation for the entire sample: $r = 0.353$, $p = 0.002$; strong correlation for females: $r = 0.516$; $p < 0.001$, nonsignificant correlation for males: $r = 0.327$, $p = 0.111$). The higher the VLI, the greater females' estimation of how much they had spoken during the day. The same is true of the self-assessed quantity of singing voice used, which was strongly and positively correlated with VLI for the entire sample ($r = 0.541$, $p < 0.001$), moderately correlated with females' VLI ($r = 0.461$, $p = 0.001$), and strongly correlated with males' VLI ($r = 0.704$, $p < 0.001$).

FIGURE 1. Vocal loading and background noise exposure for each subject. Histograms show an individual consideration of F_0 , voice SPL, phonation time, and noise SPL. Average values and standard deviations are provided for each subject according to context: professional = dark gray, extra-professional = light gray, global = medium gray.





DISCUSSION

The first objective of this study was to describe music theory teachers' vocal loading and exposure to background noise in both professional and extra-professional contexts. The results revealed that voice SPL, F_0 , phonation time, and background noise level varied significantly according to context. Vocal loading parameters and background noise exposure were much higher in the professional than in the extra-professional context. In this respect, these results are in line with past research findings on classroom teachers' vocal loading.^{11,19,21}

Apparently, music theory teachers face higher occupational vocal demands than classroom teachers. This is shown by a comparison of the current data with findings obtained by Remade et al.¹¹, who used an ambulatory phonation monitor (APM) to investigate vocal loading in female kindergarten and primary schoolteachers in professional and extra-professional contexts. APM and VoxLog may show minor deviations in their output because of differences in software and hardware. Nevertheless, a comparative study of a speaker giving a go-

minute lecture showed that, although vocal loading was slightly higher when measured with the VoxLog, both APM and VoxLog produced almost identical outputs for SPL (2.4 dB of difference), Fo (2.3 Hz of difference), and phonation time (1.4% of difference).²⁶ Taking this into account, we found that professional voice SPLs measured in music theory teachers in the present study (females = 93 dB; males = 90 dB) are substantially higher than those found in kindergarten (82 dB) and primary schoolteachers (80 dB) in a previous study.¹¹ The same holds true of mean professional Fos, which are also considerably higher in female music theory teachers (282 Hz) than in female kindergarten (268 Hz) and primary schoolteachers (253 Hz). Finally, professional phonation time was also higher in music theory teachers (females = 33%; males = 28%) than in female kindergarten (21%) and primary schoolteachers (20%). Although caution may be necessary, comparison of results obtained with different dosimeters seems legitimate. It is unlikely that higher professional vocal loading measures in music theory teachers than in classroom teachers are artifacts produced by differences in equipment.

Considering global means in both contexts, we found that music theory teachers' vocal loading is similar to measures previously found in music teachers. In the United States, Morrow and Connor¹⁰ investigated vocal loading differences between female classroom and music teachers using an APM. Classroom teachers' mean voice SPL (77 dB) was lower than that of music teachers (89 dB). In the present study, similar global means were measured for male (89 dB) and female music theory teachers (91 dB), with large SDs (14 dB) showing intersubject variations. These results support the finding that music theory teachers vocalize much louder than classroom teachers. High voice SPLs found for music theory teachers may be the result of high background noise levels during musical activities. When acquiring musical skills, students' learning is based on production of their singing voice in groups, while the teacher frequently accompanies the students by singing and playing the piano. These pedagogical methods may lead to the substantial vocal loading measured in our study. Concerning Fo, music theory teachers also exhibit values resembling those of the American music teachers: Morrow and Connor measured 236 Hz in classroom and 269 Hz in music teachers, compared with a global mean of 267 Hz in female music theory teachers. High Fos in music teachers may be related to their extensive use of their singing voice and greater Fo modulations, whereas classroom teachers mainly use their speaking voice and are likely to produce smaller Fo ranges during phonation.

Large quantities of vocal loading, as found in this sample of music theory teachers, are thought to promote laryngeal lesions because of the exposure of vocal fold tissue to potentially damaging collisions.^{13,19} However, organic changes further to excessive vocal loading are not the only hazard. High background noise levels, as measured at the workplaces of music theory teachers (79 dB), may also lead to vocal misuse (i.e., functional voice disorders).²⁷ Such dysfunctions may arise when speakers increase their voice SPL and Fo in the presence of background noise—a phenomenon known as the Lombard effect.^{16,28} Indeed, research suggests that music teachers, whose principal instrument is their voice, are particularly likely to develop voice disorders.²⁹ Against this background, it can be assumed that the population of music theory teachers constitutes a high-risk group as well. On the other hand, these teachers receive voice training during their education. It is therefore also possible that they acquire vocal techniques and strategies to use their voice in a healthier and more effective way than classroom teachers.

The second objective of this study was to understand the association between background noise level and music theory teachers' vocal loading. For this purpose, we calculated whether background noise level correlated with voice SPL, Fo, and phonation time. Note that a correlation describes the statistical association between two variables and that any causal relationship remains hypothetical.

For both genders, these results showed a strong positive correlation between background noise level and voice SPL, which is in line with past findings^{16,30,31} and reflects the Lombard effect. We assume that, for the sake of intelligibility, teachers raise their

voice in response to increased background noise. An alternative interpretation is that students raise their voices and agitation level (i.e., higher background noise) as a reaction to the teacher's loud voice. The

substantial variability of our dataset could reflect different causal links between background noise and voice levels.

Regarding the association between background noise and F_0 , correlations were only significant for females. The noisier the environment, the higher pitched their voices. This finding is in accordance with the results of Sodersten et al.³², who examined vocal loading among female kindergarten teachers by means of binaural digital audiotape (DAT)-recordings. In the present study, male subjects also tended to show higher F_0 s when background noise level increased, but this difference did not reach significance. This is in contrast with recent findings by Yiu and Yip.¹⁷ In a laboratory experiment, those authors investigated the effects of different background noise conditions on healthy speakers' voice during a 3- to 5-minute monologue with the use of an APM. Irrespective of gender, high background noise levels were associated with F_0 increases. The fact that no such correlations were found for males in our study might be due to methodological differences in tasks, environments, and sample sizes. However, it is also possible that male and female music theory teachers do apply different strategies to increase their intelligibility in noisy environments. It could be that males primarily speak louder, whereas females also increase their pitch.

A positive correlation was also found between background noise level and phonation time, which is in line with previous results on teachers and other speakers.^{16,32} This correlation was stronger in males than in females and could represent another automatic strategy to make oneself understood over background noise. Similarly, Gamier and Henrich¹⁶ found that, regardless of the type of noise presented, speakers not only spoke louder but also tended to prolong voiced speech sounds. This effect was measured for voiced consonants but was particularly strong for vowels.

In light of all three voice parameters investigated, it seems likely that background noise is at least partially responsible for the large amount of professional vocal loading among music theory teachers. Future studies with larger samples should investigate the causal relationships between these parameters.

The third objective of this study was to investigate whether VLI was reflected in the subjects' self-evaluations. The results revealed that the higher the number of vocal fold oscillations during the day (i.e., VLI), the higher the perceived vocal fatigue and the poorer the perceived voice quality at the end of the day. Poor voice quality and high vocal fatigue might be symptoms of voice overuse. If they persist for long periods of time, they may be an early sign of voice disorders. Positive correlations were also found between VLI and the self-assessed quantity of speaking and singing voice use reported at the end of the day, with the effect being more pronounced for singing voice. The fact that, for speaking voice, correlations between VLI and self-assessed quantity of voice use were only significant in females, and not in males, might be due to the larger sample of female teachers (nine females versus four males). These results suggest that music theory teachers are well aware of the amount of vocal

use and feel its effect on voice quality and vocal fatigue. In 2013, Szabo Portela et al.³³ investigated phonation times and F_0 s among preschool teachers using voice accumulation and visual analog scales. Their results showed that teachers' estimation of how much they had spoken greatly exceeded their actual voice use. However, subjective data were collected on one monitoring day only and no correlation between subjective symptoms and objective data was performed.

The present study indicates that music theory teachers are good at estimating how much they have used their voice with the aid of visual analog scales. This may not necessarily be the case for other populations. In a study of call center agents, for example, objective voice data (including VLI), recorded on four different occasions during the day, did not correlate with subjective voice problems reported with visual analog scales.²⁴ Rantala et al.³⁴ and Laukkanen et al.²⁵ recorded classroom teachers' voices before and at the end of a workday. Subjects also reported their vocal fatigue by means of visual analog scales³⁴ and questionnaires²⁵ on both occasions. Again, no correlations between objective and subjective measures were found. There are several possible explanations for these contradictory findings. Firstly, music theory teachers face very different—and possibly higher—vocal demands than classroom teachers or call center agents, which could make it easier to

detect correlations between subjective and objective voice data. Secondly, music theory teachers are likely to have a more accurate self-perception of their voice because voice evaluation is part of their day-to-day work life. Thirdly, past studies did not specifically calculate correlations between VLI and self-perceived quantity of voice use, although these are measures of the same concept. Thus, it is important not only to further investigate music theory teachers' actual and perceived voice use but also to extend this research to other populations with the aim of describing and explaining expected differences.

As this is the first study on music theory teachers' voice use, certain limitations must be acknowledged. Because of the small number of subjects, conclusions must be drawn carefully and implications may not be generalizable to other populations. Voice dosimetry is a valuable method because of its objectivity and ecological usage. However, it is related to the problem of small sample sizes because of factors such as human resource limitations, costly equipment, and skepticism among potential subjects about technical issues or the practicability of wearing a voice dosimeter. Subjective assessments therefore remain an important supplement to voice dosimetry.

CONCLUSION

The study presented here furthers our understanding of vocal demands affecting Belgian music theory teachers and the potential influence of background noise and context, using voice dosimetry and self-ratings. Voice dosimetry results consistently showed that vocal loading in this specific group of teachers was substantial and that all measured parameters were significantly higher during working hours than in nonworking hours. Overall, vocal loading values measured in music theory teachers surpass those previously found in classroom teachers, who are widely recognized to face extraordinary vocal demands. They are, in fact, comparable with measures previously found in music teachers.

Background noise levels were also found to be higher during working hours than during nonworking hours and strongly correlated with music theory teachers' voice SPL. Moreover, background noise moderately correlated with females' F_0 . Correlations with phonation time were strong for males and weak for females. These results suggest that music theory teachers' strategies to communicate over background noise may differ according to gender. Depending on the causal link between parameters, the results may indicate either that noisy teaching environments are an important factor leading to increased vocal loading or that teachers' high vocal loading increases the agitation level in the classroom and therefore its background noise.

Finally, correlations between objective and subjective data showed that daily vocal loading was reflected in the subjects' self-assessment of their voice and their estimation of how much they had spoken or sung during the day. These results support the utility of visual analog scales for self-assessments of vocal loading, but future investigations of music theory teachers and other populations are vital for confirmation. It would also be interesting to promote research into intersubject differences in terms of correlations between subjective and objective voice data and to examine the potential reasons for those differences. Finally, relationships between vocal loading self-assessments and objective measurements should be investigated by means of more comprehensive vocal doses, such as the distance dose, which encompasses voice F_0 , SPL, and duration of phonation.

Acknowledgments

We thank Lou Sfez and Alexandra Vandeveld for their help in collecting and analyzing the data.

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