TRAJECTORIES IN CLASSROOM ACOUSTICS: VOCAL BEHAVIOR OF TEACHERS

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Résumé

L'acoustique des salles de classe a été l'un des principaux thèmes de recherche de Murray Hodgson, que j'ai eu l'occasion de connaître à Rome, lors de la conférence de l'ICA en 2001, alors que j'étais au début de mon parcours, et dans plusieurs autres occasions. À Ferrara, en 2003, il a conclu son exposé sur un cours d'acoustique en classe en insinuant que les problèmes de voix des enseignants auraient dû faire l'objet d'études futures. Je travaille sur cette question depuis sept ans et ce travail résume les résultats et les perspectives relatives à l'évaluation du comportement vocal des enseignants. En particulier, la surveillance de la voix des enseignants au cours de leurs activités quotidiennes repose récemment sur des analyseurs vocaux portables équipés de capteurs de contact qui permettent de mesurer des paramètres liés à l'effort vocal, à la charge vocale, à l'intonation vocale et à la santé vocale. Les résultats obtenus lors des campagnes expérimentales menées au cours des dernières années dans des écoles de niveaux différents sont présentés dans cet ouvrage. Les relations avec l'acoustique des salles de classe, à la fois en termes de bruit et en termes de réverbération trop basse ou excessive, et les résultats subjectifs des enseignants sont également discutées.

Mots clefs: acoustique des salles de classe, contrôle de la voix, effort vocal, charge vocale

Abstract

Classroom acoustics was one of the main research themes of Murray Hodgson, which I had the chance to know in Rome, at the ICA Conference in 2001, when I was at the beginning of my working path, and to further have as scientific converser in many other occasions. In Ferrara, in 2003, he concluded his presentation of a course on classroom acoustics with the hint that the teachers' voice problems should have been object of future studies. I have been working on this matter for seven years and this work summarizes the results and the perspectives related to the assessment of teachers' vocal behavior. In particular, teachers' voice monitoring during daily working activities has been recently based on wearable vocal analyzers equipped with contact sensors, which allow for measuring parameters related to vocal effort, vocal load, vocal intonation and health. Results obtained during experimental campaigns that took place in the last years in schools of different grade are presented in this work. The relationships with classroom acoustics, both in terms of noise and too low or excessive reverberation, and the subjective outcomes of the teachers, are also discussed.

Keywords: classroom acoustics, voice monitoring, vocal effort, vocal load

1 Introduction

The research by Murray Hodgson in the field of classroom acoustics is worldwide recognized, as proved by 7 main articles and overall 25 contributions on this subject authored by him in the Journal of Acoustic Society of America.

The effect of classroom acoustics has consequences on learning of students, mostly at the lower grades of education, for which it is mandatory to guarantee speech comprehension in classrooms, and on teachers and teaching, for which it is mandatory to reduce teachers' vocal effort and load.

According to M. Hodgson *et al.* [1] "Voice problems among teachers represent a rising cause of teacher absenteeism, use of sick benefits, and stress among teachers and students. In British Columbia, the BC Teachers Federation and Workers Compensation Board has received increasing numbers of claims from teachers experiencing occupational voice problems and the percentage of teachers in the clinic population is rising."

He contributed to this subject by determining the typical long-term speech levels during lectures in classrooms at the University of BC, as well as the speech-signal to background-noise ratio, with the aim to elucidate the characteristics of classroom acoustics relevant to optimal design [2, 3].

Three billion people are the working population in the world and teachers are the 2% (Europe: 2.1%; USA: 2%), i.e. 60M.

Teachers of different types and levels, including teachers of physical education and music, are some of the most affected professional figures. In the world, 6M of teachers suffer of vocal pathologies and 1M only in Europe. Teachers vibrate their vocal folds 25% of the time that they teach [4], as opposed to 12% of time that they do not teach [5] and suffer from voice disorders twice as much as other professional groups. Teachers with documented voice disorders are up to 33% [6] and those with perceived ones are up to 50% [7]. Voice disorders are not still recognized as

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occupational disease. They are caused by incorrect use of voice or poor acoustics in the environment where the voice is used.

A long-term voice monitoring is needed in order to prevent damages to the vocal apparatus that are related to vocal effort and load. Particularly, voice monitoring is aimed to warn the talker against at-risk situations, to highlight existing or incoming problems to the vocal apparatus, and to select suitable spaces for the vocal activity. Voice monitoring should be done without the influence of background noise and for this reason contact microphones which estimates vocal parameters from the skin vibration at the speaker's neck are recommended [8].

Vocal analyzers based on contact microphones should be qualified in terms of uncertainty of the measured quantities, particularly for the most important ones such as the mean voice sound pressure level and the mean fundamental frequency [8-10].

2 Voice monitoring of teachers

In order to perform teachers' voice monitoring during teaching time, our research team at the Politecnico di Torino, in collaboration with S.C. ENT 2 U. of the University of Turin and PR.O.VOICE Ltd, start-up incubated in I3P of the Politecnico di Torino, designed two wearable devices based on the former Voice Care™ technology [11, 12]. The light version, named "Vocal Holter App", can be installed on a common smartphone, and the pro version, "Vocal Holter Med™", made up of a dedicated device which performs more extensive and personalized analysis useful to physicians and speech pathologists.

The devices estimate vocal behavior in terms of vocal effort, vocal load, vocal intonation and health. Sound Pressure Level (SPL), phonation time percentage (D_t), Fundamental frequency (F_0) and Cepstral Peak Prominence Smoothed (CPPS), are the main parameters related to the four previous categories. Measurements of these and other parameters are performed at a logging interval of 46 ms. The former Voice Care device was instead set to a logging interval of 30 ms, which allowed to detect the inter-syllabic pause [11].

In a comparison with other three commercial dosimeters the Voice Care device resulted one of the most accurate in the determination of the mean voice sound pressure level and of the mean fundamental frequency [9].

CPPS is a novel parameter considered one of the most promising predictors of dysphonia and its severity [13]. Vocal parameters are provided in the form of statistical metrics derived from the distributions of occurrences. Comparison among results can be made as the measures are also characterized in terms of uncertainty.

Some measurement campaigns have been carried out in-field along the last seven years, with teachers of different grades who taught in schools with different acoustics [4, 14-15]. Results are presented on vocal effort and load and on the effect of classroom acoustics (noise and reverberation) on vocal behavior of teachers. Subjective outcomes have been also gathered and commented.

3 Results

3.1 Vocal effort and load

A vocal effort of 71 dB, SPL_{eq} @1m from the teacher's mouth, has been found on average for both primary and secondary school teachers [14, 15], i.e. between "Raised" and "Loud" [16]. During plenary lessons, primary and secondary school teachers were characterized by a phonation time percentage from 26% to 29% and of about 40%, respectively [14, 15].

A significant difference was found between the morning and the afternoon teaching periods, concerning mean voice sound pressure level, which on average increased during the afternoon by about 5 dB [14].

Moreover, as a result of a longitudinal study in secondary schools, teachers who worked in bad classroom acoustics showed a 2 dB increase in the vocal effort and a 10% decrease in the voicing time percentage at the end of the school year compared to the beginning [15].

3.2 Vocal fatigue

Vocal fatigue is here considered as a negative vocal adaptation that occurs as a consequence of prolonged voice use in critical conditions [17]. In this context, a tendency to increase the voicing periods as the reverberation time increases was on average observed for university professors and school teachers, and more generally for speakers who are highly motivated to make themselves understood in a perturbed speaking situation [18]. Particularly, reverberation time higher than 0.9 s in classrooms implicated higher accumulations of voicing periods for teachers, thus suggesting that vocal fatigue is highly related to classroom reverberation time [19].

3.3 Noise and Lombard effect

The involuntary tendency of speakers to increase their voice level as the noise level increases, in order to improve intelligibility of the speech signal is called Lombard effect.

Lombard effect with slopes between 0.4 and 0.7 dB/dB was found on average during plenary lessons in primary and secondary schools [4, 14-15]. A longitudinal study carried out in secondary school classrooms showed as this effect was not maintained at the end of the school year [15]. In both the school typologies, it was found an increase in the mean fundamental frequency with the increase in background noise at a rate of 1-3 Hz/dB.

3.4 Effect of reverberation

The reverberation time that should be set in primary and secondary school classrooms in order to minimizes the voice level should be in the range between 0.7 and 0.8 s, at mean frequencies [4, 14-15]. Teachers raise their voice at both lower and higher reverberation time. In the case of lower reverberation time teachers rise their voice due to the lack of voice support from the room [20], while in the case of higher reverberation time it is supposed that they rise their voice due to the amplified background noise. A

tendency of background noise level to increase with increasing reverberation time was in fact observed at a rate of 13 dB/s [14].

The minimum speech level that was measured on average in the case of optimal reverberation time was approximately 65 dB SPL_{mean} at one meter from the teacher's mouth, which corresponds to a "normal" vocal effort [16].

Another research revealed that under simulated acoustic environments talkers adjusted their vocal effort linearly with the Voice Support, which represents the degree of amplification offered by the room to the voice of a speaker, at his own ears. The slope of this relationship, called the room effect, of -0.24 dB/dB, was significant only in the case of noise levels of approximately 60 dB [21]. This could be seen as an opposite result compared to the previous finding obtained in-field, but it should be noted that in laboratory a speech shaped noise has been used for the experiments, which is a stationary noise sequence whose spectrum follows the long term average speech spectrum, and not a real talking noise that can be find in real classrooms. Further investigations on this aspect should be done in the future.

3.5 Subjective outcomes

On average, the vocal comfort for speakers was found to be more closely related to noise annoyance than to room reverberance [21].

In the case of absence of noise, Decay Time at the ears is an acoustical parameter strongly related to the perceived sensation of vocal comfort, which is defined as the average of the subjective impression related to several aspects of voice use in different acoustic environments [20]. Decay Time at the ears is a decay time derived from an impulse response measured from the mouth to the ears of a talker. Particularly, a recommended Decay Time at the ears of 0.49 s and a range between 0.29 and 0.53 s were found to minimize vocal effort and maximize the vocal comfort of primary school teachers [14]. This result is in agreement with a study conducted with speakers in laboratory [20].

4 Conclusion

The work by M. Hodgson in the ambit of teachers' voice was mainly focused to find algorithms for the estimation of the speech sound pressure level in classrooms and to its propagation in different room acoustic conditions. According to his plans dated 2003, teachers' voice problems should have been object of future studies.

Thanks to his suggestion, progresses have been made so far on the topics of vocal effort and vocal load, vocal fatigue and health, influence of noise and reverberation on vocal output and vocal comfort, for teachers of different grades of education. All this thanks to voice monitoring.

Future research is needed to investigate relationships between voice emission and perception in realistic complex and challenging auditory scenes.

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