Acoustics – Loading of teachers and children

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INTRODUCTION

School classroom is the working environment of students and teachers. One of the main purposes of attending a school is learning. In the process, most of the time the teacher is the giving party and the student the receiving party. For a best possible result, both of them need circumstances that support the target activity. The circumstances include the physical environment, the classroom. Factors that are loading human function are found in noise and acoustics, indoor air quality, working postures and stress.

Noise has several effects on human function. It has already been shown that noise and reverberation affect voice production (Sala et al 2002) and speech hearing (Neuman et al 2010), but also they affect memory and are associated with working memory capacity (Kjellberg et al 2008, Ljung&Kjellberg 2009). It also seems that memory is more sensitive affected by noise and reverberation than is speech perception (Ljung&Kjellberg 2009). Noise also has physiological effects on hart function and circulation, endocrine, metabolism and immune system. Noise increases stress and affects sleep quality, increase risk for hypertension and heart attack (Babisch 2006, Ising 2004).

Indoor air quality has effects on respiratory tract mucous membranes: low relative humidity of the air dry mucous membranes and toxins may cause inflammation (a disease) and through that decrease resistance against mechanical trauma to the mucous membrane of vocal folds that is caused speaking in noise. Bad working postures increase muscle tension and stress affect voice production.

It is known that classrooms are noisy and acoustics is not as good as the activity would require (Sala et al 2013a, 2013b). Noise and poor acoustics may have effects on humans in a complicated manner and different factors may interact. Speaking in noise increases vocal loading and thus may result in a voice disorder with a hoarse voice. Furthermore speaking with a hoarse voice decreases speech perception of children.

Voice symptoms are charted to find out the dysfunction of the vocal organ and a voice disorder. In our studies the prevalence of voice disorders is the higher the more demanding are the speech communication conditions. In preschools the activity noise levels are high (Sala et al. 2002, Sala et al. 2013) and also the prevalence of voice disorders is high (Sala et al. 2001). Speaking in noise may even cause organic damage to vocal folds (vocal nodules). (Sala et al 2001)

Voice Handicap Index measures handicap due to voice symptoms/disorder (Jacobsen et al 1997). The degree of handicap depends on the degree of difficulty of the voice disorder and circumstances of the speech communication. With a mild voice disorder handicap may be high when speaking long times in demanding environment.

PURPOSE OF THE STUDY

The purpose of this study was to find out the connections of environmental factors with loading factors such as voice production, recovery, noise annoyance and behavior of students.

METHODS

The study included 40 ordinary closed classrooms from 14 different elementary schools from different parts of the country. The mean floor area of the classrooms was 63 ±7.5 m2 and mean volume 199±26 m3. A total of 40 teachers from these school classrooms participated in this study. The measurements were made during working day, including samples before and after working day.

Voice ergonomic risk factors were assessed according to the Voice Ergonomic Assessment in Work Environment—Handbook and Checklist (VEAW; in Finnish and Swedish) (Sala et al 2009). They were (1) working culture, (2) noise, (3) indoor air quality, (4) working posture, (5) stress, and (6) access to a sound amplifier as an aid to voice production.

The parameters that were used to describe acoustic properties of the room were reverberation time (T_{60}), early decay time (EDT), room gain (G), the ratio of early and late sound energy arriving to the listener (C_{50}, C_{80}), ratio of early arriving sound energy to overall sound energy (D_{50}), Speech Transmission Index (STI), rate of spatial decay of sound pressure levels (DL_2) and Spatial sound distribution (DL_f). The acoustic parameters were measured in unoccupied but furnished classrooms (N=40). Acoustical parameters were measured, calculated and presented according to the standards ISO-1457, ISO-3382 and IEC 60268-16.

Acoustic intervention was performed using sound absorbing and reflecting materials in eight classrooms. The acoustic parameters were measured after the intervention.

Background noise levels caused by the heating, plumbing, air-conditioning and electric appliances of the school buildings were measured in unoccupied classrooms during a break between lessons. The measurement location was in the center of a classroom. The sound level was measured as $L_{Aeq1min}$.

Activity noise levels were measured during classroom instructions and noise during breaks was excluded. The mean measurement period was 4 hours (SD ±0.7, min. 2 and max. 4 hours). Precision sound level meter was located at the back part of the room near the right corner at 2 meters from the walls.

Voice symptoms were inquired with a questionnaire used in several studies of prevalence of voice disorders (Simberg et al 2001, 2005, Sala et al. 2001). Voice Handicap Index measures handicap due to voice symptoms. (Jacobsen et al 1997) There are 30 different statements on voice handicap. The answers were scored on a five-point scale (0 never, 1 almost never, 2 sometimes, 3 almost always, and 4 always). Total points are 120 and the higher is the index value the greater is the handicap.

Voice loading was measured using Ambulatory Phonation Monitoring method (APM, KayPentax Model 3200). It collects data on phonation time, voice frequency and voice intensity 20 times per second. The phonation parameters were measured during the whole work day. Before starting the measurement, the equipment was calibrated.

Acoustic parameters of teachers' voices were measured before and after the working day from spontaneous speech, text reading, and sustained phonation with a vowel /a/. The voice samples were recorded before work

and after it. F_0 and SPL were analyzed from the spontaneous speech. The tilt of a sound spectrum slope (alpha ratio, the relationship of voice energy levels between SPL 50 Hz–1 kHz and SPL 1–5 kHz) was calculated from the speech sample. Perturbation variables jitter and shimmer were measured from the sustained phonation.

Eleven statements were used to chart difficulty of recovering from the working day and the answers were given in dichotomous categories. (Van Veldhoven et al 2003)

Noise annoyance was inquired in teachers' with the questionnaire introduced by Fyhri Aslak, Klæoe R. (2009). It is inquired if the noise can be heard and if it is very, some or not at all annoying. There were eight possible noise sources. The annoyance was inquired the pupils by the questionnaire introduced by Shield and Dockrell (2004). In that there were ten different noise sources and the answer possibilities were depicted with five icons from a laughing to a sad one.

Teachers evaluated the behavior of students according to Conners (1997). Questionnaire was prepared for teachers' use. It includes ten statements about behavior of students. The answers are given in four alternatives: do not agree, some agreement, quite good agreement, agree fully.

RESULTS

Voice ergonomic risk factors found were working practices (52 %), Indoor air quality (44), lack of sound amplifiers (40), working postures (33 %), noise and acoustics (32 %) and stress (30 %).

Voice symptoms were common, 45 per cent of teachers had two or more symptoms and there was no teacher who had had no voice symptom during the last year. The more voice ergonomic risk factors found in the classroom the higher were the teachers' total scores on voice symptoms and VHI. Noise correlated significantly with VHI-Physical and VHI-Total scores. Stress was the factor that correlated most strongly with voice symptoms. Poor indoor air quality increased the occurrence of laryngitis (inflammation of mucous membranes). The mean value for the indoor air scores was higher (mean, 8.2; SD, 1.2) in the classrooms of those participants who had suffered from laryngitis in the past 12 months than in the classrooms of the teachers without the disease (mean, 6.7; SD, 2.2). The difference was significant at the P level of 0.051 (z¼_1.994).

Voice symptoms and Voice handicap index decreased after acoustic treatment. However the change was not statistically significant.

Loading of vocal organs was measured with APM-method during the working day. 58 per cent of teachers were spoken with normal or relaxed voice level and 42 percent with raised or loud level as categorized according to ISO 9921-1 (1996, 2003) standard.

Vocal loading decreased after acoustic treatment. The speech levels of male teachers decreased by 5 dB, fundamental frequency 11 Hz in female teachers and speaking time in female speakers 2 % and male speakers 4%.

In this study we hypothesize that speaking long times in noisy surrounding causes chronic changes to voice production that can be found by measuring acoustic characteristics of the voice. The background noise

correlated most often with the F_0 of males and voice levels, while activity noise correlated with alpha ratio and perturbation values. Teachers working under louder background noise spoke more loudly before work than those working in lower noise levels. Voice variables generally changed less during work among teachers working in loud activity noise than among those working in lower noise levels.

Room acoustic parameters correlated with voice variables. Voice levels before and after work, were associated positively with G values but negatively with T_{60} values. STI correlated positively with shimmer of the voice samples recorded before work.

Acoustic intervention had a favorable effect on recovery of teachers after work day from the loading symptoms: the recovery happened faster after than before acoustic intervention. After acoustic intervention the difficulties in recovery decreased from 30 to 22 units. All of the teachers experienced the speech of the pupils annoying or very annoying. Also the noise, that carry from corridor are considered as annoying by the teachers. After acoustic intervention noise annoyance did not decrease, instead the noise from corridors, seem to be annoying by two teachers more than before the intervention. Instead, remarkable effect was found in the perceived reverberance i.e. the experience if the room makes reverberant impression. After acoustic intervention the number of teachers who considered the perceived reverberance of the room as annoying or very annoying decreased.

Pupils experienced generally noise as most annoying and the specific noise source that was most annoying was the speech of others in the room. Annoyance of different noise sources or situations decreased systematically after acoustic intervention. After the acoustic intervention noise was systematically less annoying. There was a small but systematic decrease of noise annoyance among students. Most significant finding was the noise situation when students are speaking

The behavior of students was inquired with the questionnaire prepared for teachers. After the acoustic intervention there were fewer misbehaving students. Most frequent finding was that the students are restless, hyperactive, inattentive, and interrupt others. Teachers observed these features in fourth or fifth part of the pupils. After acoustic intervention different misbehavior features decreased systematically nearly in all the subjects of the misbehavior features.

DISCUSSION

Loading do not necessarily mean overloading. The definition of physiological loading means function within the normal limit and overloading means pathological function and tissue damage. Symptoms are the feelings/experiences of the subject. Until now we do not know the boundaries of physiological loading and overloading (pathological loading) when all the loading factors and target functions are taken into account. Here loading factors such as noise, acoustics, indoor air quality, working postures and stress i.e. voice ergonomic risk factors are included.

It has been found that voice disorders are common among professionals with demanding speech communication conditions (Sala et al 2001). In our studies, we considered that one having two or more voice symptoms weekly or more often have a voice disorder. In this study nearly half of the teachers had a voice disorder according to our definition. There was no teacher who had had no voice symptom during last year.

In this study teachers recruiting to the study were random selected and in spite of that, voice loading effects were found. Also among students there are several with characteristics (foreign language, bilingual, language disorders, hearing loss, restricted working memory capacity etc.) that restrict functions to reach normal level. That is why different external loading factors should be restricted as much as possible. In this connection this means to create (plan and build) classrooms/learning spaces with good acoustics and low noise levels.

In the study all the environmental factors were affected at the same time. The factors may have additional effects to each other. For example if indoor air quality is poor, it may cause mucous membrane to dry or to be inflamed and as a consequence of that be less resistant to mechanical trauma that voice production causes to vocal fold mucous membranes. As the voice problems are such common and noise and poor acoustics are one of the risk/loading factors, the noise should be eliminated with structural and functional measures.

CONCLUSIONS

Activity noise and acoustics have connections with

- Voice loading (symptoms, handicap, voice level, frequency and tilt of speech spectrum)
- Perceived reverberance of the rooms both in teachers and students
- Noise annoyance experienced by the students
- Recovery of teachers after working day
- Behavior of the students estimated by the teacher

Favorable effects of the acoustic intervention were found in

- Reverberation time
- Speech transmission index
- Background noise levels
- Activity noise level
- Voice loading of teachers
- Perceived reverberance of the rooms both in teachers and students
- Noise annoyance experienced by the students
- Behavior of the students estimated by the teacher

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