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Technical note

Acoustics and activity noise in school classrooms in Finland

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ABSTRACT

School classrooms are learning spaces for children and workplaces where a teacher's most important tool, his or her voice, is subjected to considerable loading. Because noise has several detrimental effects on human functioning including speech production and perception, a noiseless environment and good acoustics in classrooms are important. The main aim of this study was to investigate the classroom as a sound environment and to ascertain the effect of acoustics.

Activity noise levels, background noise levels and acoustics were measured in school classrooms (N = 40), and the associations between these were studied. The acoustics of measured in these classrooms were compared to the values of the Finnish national standard. Acoustic parameters (reverberation time and Speech Transmission Index, STI) and background noise levels were measured in unoccupied classrooms and activity noise levels were measured during classroom instruction.

The results showed that only few classrooms fulfilled the acoustic criteria of the Finnish national standard and no classroom fulfilled the criterion for acoustics measured according to the STI. In most of the classrooms the background noise level was higher than recommended and activity noise levels were high for listening and communication. According to the results, the acoustic environment in these school classrooms was detrimental to speech communication and learning. This also implies a risk of occupational voice disorders. Acoustic ergonomics should be taken into account and acoustic standards should to be fulfilled when new schools are built and old ones refurbished.

1. Introduction

1.1. School classrooms are learning spaces

A school classroom is an environment where a teacher works and children and young people acquire skills and knowledge, and prepare for higher education. To for all this to happen, a classroom should have conditions that make it easy to discriminate between words, understand spoken language, and also remember the content of the message. If these premises are fulfilled, speaking and hearing conditions are appropriate for learning. Standards are an attempt to set appropriate levels for noise and room acoustics in order to limit the deleterious consequences of noise. Unfortunately, optimal learning and communication conditions during teaching were not found in many schools [1,2]. The main external factors impairing communication conditions in classrooms are noise and poor acoustics.

Noise is always non-informative sound that has several detrimental effects on human functions. Poor acoustics further exacerbates the harmful effect of noise by making it more continuous and restricting its attenuation [3–5]. Although a good learning environment is of the utmost importance, so far little is known about the acoustic aspects. This article describes how classroom sound conditions affect speech communication and what is so far known about the sound environment of a classroom. The goals of this research are (1) to document the activity noise levels during classroom instruction, (2) to determine if background noise levels affect activity noise levels, and (3) to ascertain if room acoustics affect activity noise levels.

1.2. Consequences of noise to a listener

Speech perception depends on speech loudness, which in turn depends on speech production, the location of a speaker, the distance between a speaker and a listener, the acoustics of the room and the presence of noise during speaking. Noise impairs speech perception in children [6] and adults [3] and in children even more severely [7]. Noise necessitates greater listening effort [8]. Children

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with specific language impairments [9,6] or hearing loss [10] perform more poorly in noisy environments than do children with normal language development and hearing. Speech perception during noise is especially difficult for individuals with low working memory capacity [11], and among such individuals are children with central executive deficits (ADHD, ADD) or language impairments, for instance [12–14].

Noise exposure has been shown to change sound processing in the adult brain [15]. This very likely also concerns the child's immature brain, but the topic has not yet been studied. Cognitive functions known to be susceptible to the effects of noise are attention, language learning, mathematical performance and memory [16–21]. Noise has also been found to have a dose-response function in the cognitive functioning of children: the higher the noise levels, the greater the effect [22].

Noise is also annoying. According to a study made by Lyberg Åhlander et al. almost every teacher (92%) has felt disturbed by noise due to the activity of pupils, ventilation and other equipment in the building [23]. Children also perceive noise and it annoys them, too [22,24]. Intermittent noise is especially irritating [16].

1.3. Consequences of noise to the speaker

A speaker reacts to noise. Her or his intention in communicating is to be heard and understood. To overcome the effects of disruptive noise, a speaker has to use a raised, loud, very loud or shouting voice [25]. The phenomenon is known as the Lombard Effect [26,27]. Raising voice loudness mostly happens unconsciously. During noise a speaker's speech prosody also changes. Talkers speak louder and slower, raise their vocal pitch, introduce changes in the short-term power spectrum and in the pattern of vowel formant frequencies [28]. These means also that more energy shifts towards the higher frequencies making the speech easier for a listener to perceive in noise [29].

Although changes in the voice to adapt to noise support the transmission of a verbal message, they may also have harmful effects on the voice organs. Using a raised voice increases the risk of voice disorders [4,29] which are indeed very common among teachers [30–33]. This also confirms findings according to which environmental factors have a more deleterious effect on voice disorders than do genetic factors [34,35]. Concern over noise in classrooms is timely because the prevalence of voice disorders has increased markedly in the last two decades [32].

1.4. Activity and background noise in classrooms

1.4.1. Activity noise

In the last 20 years pedagogical methods and teaching have changed and affected noise levels during teaching. The teacher formerly taught at the front of the classroom and the pupils sat quietly at their desks. Although a recent study found that in a classroom one person was speaking for nearly 46% of the teaching time [36] a pupil is no longer seen as a passive learner but an active knowledge seeker. This means child orientated and dynamic teaching methods including group discussions, learning-by-doing exercises and teamwork. All these activities increase noise. Moreover, activities themselves – handling various objects, shifting chairs and tables, moving around – also raise noise levels. This kind of noise can be called activity noise, which has so far attracted the attention of only a few researchers (see below).

Activity noise impairs speech perception and speech communication since it consists of the hum of many voices, which is a strong speech masker [29]. Activity noise levels vary depending on the subject being taught, the number and age of the pupils, and the pedagogical ideology [36–38]. Learning spaces for five- and six-year-old children are among the noisiest places [38], which means that noise levels are highest when they should be lowest. Table 1 presents data on activity noise levels in schools. The results are not comparable with each other because the number of classrooms has usually been small, measurement periods have been short and the measurement methods have varied.

1.4.2. Background noise

Background noise consists mostly of sounds from traffic and equipment such as heating, plumbing, ventilation, air-conditioning and electrical appliances installed in the building. Standards specifying background noise levels for classrooms have been set in many countries. For instance in Finland, the limit for an equivalent continuous sound level is 28 dB (SFS5907) [40] and in the USA 35 dB (ANSI/ASA S12.60) [41]. In schools of several countries, that is, in several cultural environments, noise levels have been found to exceed the levels recommended [1,2].

Table 1
Activity noise levels in elementary schools and preschools.

Study	N	L_{Aeq} (dB)	L_{90} (dB)	Measured period
Studies from elementary school classrooms				
Pekkarinen and Viljanen [1]	20 rooms	67 ± 5 Range 58–79	49 ± 6 Range 40–58	20–30 min
Shield and Dockrell [2]	140 rooms	56–77		2 min
Shield et al. [36]	80 rooms	62–68	49–57	[a]
Oberdörster and Tiesler [54]	5 room	59–70	52–61[b]	5 min
Larsen and Blair [55]	4 rooms 3 schools	From 58 ± 6.1–64 ± 5.9 Range 42–100	–	100 min
Studies from preschool[c] activity rooms				
Sala et al. [4]	51 rooms	67 ± 3 Range 62–73	43 ± 2 Range 39–47	7 ± 0.5 h
Södersten et al. [56]	10 teachers	76 Range 73–78	–	–
McAllister et al. [39]	10 children 3 preschools	83[d] Range 82–84	–	125–193 min
Sjödin et al. [57]	101 teachers 17 preschools	71 ± 3[e] Range 60–85	–	5 working days

[a] Whole duration of the lesson.
[b] L_{A95}.
[c] The studies were from Sweden or Finland where a child attends a preschool at age six.
[d] Measured at the ears of children.
[e] Measured on the back of the head of the personnel.