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Speech-Language & Audiology Canada
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SAC Position Paper on

Classroom Acoustics

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A position paper represents the direction SAC has taken on a particular topic or provides guidelines for particular areas of practice. These positions are time-bound, representing the thinking at a particular point in time.

Position

It is the position of Speech-Language & Audiology Canada (SAC) that Canada and its provinces and territories must adopt changes to their respective building codes to include standards for classroom acoustics. These standards are essential to optimize learning, teaching, overall health and quality of life. SAC recognises the detrimental impact of poor classroom acoustics on student learning as well as the negative health effects on **educators** and students in early childhood and **school settings**.

Background

The ability to hear, listen and process auditory information effectively is crucial to learning for all students. Although classroom configurations and teaching styles have changed throughout the years, the issue of background noise in classrooms has remained a consistent challenge (Crandall and Smaldino, 2000; Shield, Greenland, & Dockrell, 2010). Many studies have suggested that recommended acoustical standards for noise levels are not achieved in a majority of classrooms (Crandell & Smaldino, 2000; Rubin, Flagg-Williams, Aquino-Russell & Lushington, 2011). Children often work in classrooms with noise levels equal to or higher than the level of the educator's voice, which leaves students listening in a "sea of noise" (Anderson, 2004; Hodgson & Nosol, 2002; Bradley, 2002b). It has been shown that the average level of background noise in a classroom can range from 32 to 67 **decibels** (dB), where 60 dB is equivalent to the sound of a small hair dryer operating (Knecht et al., 2002). A degraded acoustic signal increases cognitive demand and results in mishearing and misunderstanding as well as issues with language processing, memory, attention, stress and fatigue (Peelle, 2018).

Classroom noise has the potential to disrupt educational activities and disturb students' perception of speech (Peelle, 2018; Sato & Bradley, 2008a, b; Hodgson & Nosol, 2002; Shield & Dockrell, 2003). Common sources of noise in classrooms include heating, ventilating and air-conditioning equipment, exterior noise leaking through windows and doors, as well as noise from adjacent rooms and hallways coming through walls and doors (Nelson, 2010).

Reverberation, the persistence of sound reflections from hard walls, floors and ceilings, also creates unwanted noise and contributes to poor classroom acoustics (ANSI, 2010; Bradley 2002a; Yang & Bradley, 2009).

Research has shown that noise and poor reverberation adversely affect typical young children more than typical adults. These factors, in addition to the inherent high demands on listening and auditory processing in classrooms and the immature listening skills of children due to neuromaturation, create barriers to learning that place all children at educational risk. (Millett, 2010; Bradley, 2002b; Sato & Bradley, 2008(a/b); Crandell, C. & Bess, F. 1986).

Specifically there are a number of individuals within the classroom setting who are particularly affected by poor classroom acoustics.

These groups include children with:

- Fluctuating hearing loss from temporary recurring ear infections (Bess, 1998; Niskar et al., 2000; Crandell, 1993; ASA, 2003)
- Permanent hearing loss (Crandell, 1993; ASA, 2003; Bess et al., 1998)
- Learning disabilities (Cunningham et al., 2001, Bradlow, Kraus, & Hayes, 2003)
- Auditory processing disorders (Cunningham et al., 2001)
- An English as a second language background (Crandell & Smaldino, 1994; Mayo & Florentine, 1997; Gelnett et al., 1994) or a language background other than the language of instruction
- Speech and language disorders (Klatte, Bergström, & Lachmann, 2013)
- Emotional and behavioral difficulties (Seltz, 2001; Maag & Anderson, 2006)

Furthermore, poor classroom acoustics can have significant psychological and physical impacts on students and educators (Hétu et al., 1990; Picard & Bradley, 2001; Bradley, 2002b; Sato & Bradley, 2008b, Tiesler et al., 2015).

These impacts include:

- Elevated levels of stress, high anxiety, increased annoyance, sleep disruption, depression, fatigue and increased risk of cardiovascular disease (Doherty, 1999; Evans & Johnson, 2000; Glass and Singer, 1972; Kalveram, 2000; Kryter, 1994; Kersten, 2015; Swinburn et al., 2015).
- Compromised physical and mental function, including chronic psychological distress and a decline in cognitive processes (Hughes & Jones, 2003; Banbury et al., 2001; Sandrock et al., 2009; Grebennikov and Wiggins, 2006; Kristiansen et al., 2014; Kjellberg et al., 2008; Ljung et al., 2009).
- Elevated **vocal load**, which increases proportionally with levels of background noise. The **Lombard effect** predicts that educators speak louder in noise. (Sato & Bradley, 2008a; Whitlock et al., 2006; Calosso et al., 2017; Kristiansen et al., 2014; Guidini et al., 2012; Sodersten et al., 2002).
- A high prevalence of **occupational voice disorders** among educators often resulting in missed teaching days. Common symptoms include: vocal hoarseness, vocal strain and vocal fatigue (Gotaas & Starr, 1993; Titze, Lemke & Montequin, 1997; Smith, Gray, Dove, Kirchner & Heras, 1997; Russell, Oates & Greenswood, 1998; Mattiske, Oates & Greenwood, 1998; Smith, Lemke, Taylor, Kirchner and Hoffman, 1998; Rantala, Vilkman & Bloigu, 2002; Roy et al, 2004; Laukkanen et al, 2008; Guidini et al, 2012; Kristiansen et al, 2014; Remacle, Morsomme and Finck, 2014; Rantala & Sala, 2015; Calosso et al, 2017).

Rationale

There continues to be a need to advocate for improved classroom acoustics in Canada along with the development and adoption of acoustic standards specifically for classroom environments. Designing listener-friendly classrooms requires the expertise of architects, acoustical engineers, mechanical consultants and audiologists who understand the importance of classroom acoustics. Many architects and designers are not aware of the detrimental effects of poor acoustical conditions in schools. It is crucial that those involved in designing or constructing educational facilities are aware of the impact that poor acoustics may have on both educators and students.

Canada's National Building Code (NBC) does not explicitly include acoustical standards for classrooms. Building codes are legislated at the provincial and territorial levels, however most provinces and territories rely on the NBC as a guideline in the development and adaptation of their own codes. Research into the building process suggests that building costs to implement acoustic improvements during construction can be significantly lower than the cost of implementing such improvements after construction (James, Stead, Clifton-Brown, & Scott, 2012; Lubman & Sutherland, 2001; Mealings, 2016; "Counting the costs of noisy vs. quiet classrooms", 2003).

Despite documented evidence of the detrimental impact of noise in the classroom, acoustic conditions in many Canadian schools remains poor. (Sato & Bradley, 2008a; Bradley, 2002b; Hétu, Truchon-Gagnon & Bilodeau, 1990; Yang & Hodgson, 2005). Children's speech comprehension can be reduced when the educator has a vocal impairment (Rogerson & Dodd, 2005). Educator absences due to occupational voice disorders disrupt instructional continuity. Furthermore, extensive use of sick leave benefits, workers' compensation claims and employment of substitute educators result in increased costs to the education system.

Recommendations

1. Ensure new and renovated schools in Canada are built with acoustical features that are consistent with current evidence-informed acoustic standards for classrooms. Examples of standards that could be adopted or adapted include:
    - The American National Standards Institute (ANSI) standards which provide design criteria and guidelines for new and refurbished classrooms and other learning spaces. ANSI recommends that unoccupied classroom levels must not exceed 35 dBA, the **signal-to-noise ratio (SNR)** should be at least +15 dB, and reverberation time (RT) should not exceed 0.6-0.7 seconds (ANSI, 2010).
    - The World Health Organization (1999) standards which recommend that the ambient noise level in an empty classroom be no greater than 35 dB and the noise level in an occupied classroom should not exceed 40-50 dBA.

2. Take steps to minimize noise within the classroom:
    - Walls between classrooms, hallways and outdoors should be properly acoustically sealed and there should be no gaps between the walls and ceiling and floor. Open concept classrooms are not acceptable. Speech from other classrooms should not be intelligible and noise from the hallway and outdoors should be minimized.
    - Noise from tables, chairs, and children's feet should be reduced by using noise reduction devices such as felt pads or specialty products that cover the bottom of tables, desks and chairs. Minimize other sources of noise in the classroom, which may come from activities aimed at stimulating learning such as aquariums, or activity centres.
    - Mechanical noise should be kept to the lowest level possible within classrooms including sounds from heating, ventilating and air-conditioning (HVAC) systems, which can be primary sources of internal classroom noise. Ducting or noisy equipment should be located in hallways and away from the classrooms. Where possible, low noise equipment should be chosen.

3. Adopt measures to optimize the signal-to-noise ratio:
    - **Classroom audio distribution systems (CADS)**, formerly known as sound field amplification systems, should be used, when appropriate, to achieve clearer speech signals (Larsen & Blair, 2008). With these systems, the signal level is greatly improved since only the voice at the microphone is amplified, not the background noise.
    - In situations where room design results in poor acoustics, reverberation and noise reduction must be addressed before CADS are added to a classroom. This ensures that each child has full access to an optimum signal and improves learning conditions.
    - Research supports signal-to-noise ratios that ensure a educator's voice is at least 20 decibels louder than the background noise (Bradley, 2002b; Sato & Bradley, 2008 a/b).

4. Optimize reverberation characteristics:
    - Reverberation time should be minimized as much as possible to optimize learning (ANSI, 2010). This can be achieved by installing sound absorbing material (acoustical wall panelling or treated ceiling tiles, soft seats, carpets, drapes, etc.) that significantly reduces unwanted reverberation. Material with good absorption coefficient should be chosen. Hypoallergenic materials should be used where possible.
    - Lower ceilings reduce the volume of the room thereby reducing reverberation.

5. Consult with audiologists and other key stakeholders such as speech-language pathologists in the planning and remodeling of schools to ensure that optimal conditions are met for children's developmental and learning needs and educators' vocal health. Furthermore, audiologists and speech-

language pathologists should be involved in interprofessional efforts to mitigate the effects of poor classroom acoustics on students and educators.

Definitions

Classroom Audio Distribution Systems (CADS): formerly referred to as sound field amplification systems. CADS are designed to address poor classroom acoustics, thereby benefiting students and educators. The educator wears a small microphone and his or her voice is broadcast to loudspeakers placed strategically throughout the classroom. This creates a uniform distribution of the sound of interest across the classroom and provides a modest improvement in the signal-to-noise ratio (educator's voice compared to background noise). Thus, students in the back of the room can hear as clearly as those in the front.

Decibel (dB): The decibel is a degree of loudness or is a unit used to measure how powerful or loud a sound or signal is using a logarithmic formula. A-weighted decibels (dBA) are used to account for the relative loudness of the human ear, with less emphasis on very low and very high frequency sounds.

Educator: a person who provides instruction or education in the classroom environment. Most research in classroom acoustics has been focused on the classroom teacher.

Lombard effect: Tendency for people to raise their voices and/or increase vocal effort in noisy environments (Lane & Tranel, 1971; Van Heusden, Plomp & Pols, 1979; Calas, Verhulst, Lecoq, Dalleas & Seilhean, 1989; Junqua, 1993; Summers, Pisoni, Bernacki, Pedlow & Stokes, 1998).

Occupational Voice Disorder: A voice problem experienced by individuals who rely heavily on speech/voice production to engage in their occupation. The voice problem may be characterized by symptoms such as vocal hoarseness/strain/fatigue, which are exacerbated by vocal use in the workplace. Approximately 13% of the population has a profession that relies on voice as a primary tool. Such professions include educators, sales personnel, actors and singers, and TV and radio reporters. Educators especially, suffer from voice-related medical problems.

Reverberation (Echo): the persistence of sound in a room, after the source has stopped generating energy, is what we call reverberation. It is the phenomenon of overlapping of sound caused by multiple reflections. Energy is lost at each reflection and the sound eventually becomes inaudible. It is measured in terms of Reverberation Time (RT). It is defined as the time it takes for sound to decay 60 dB or 1 millionth of its original sound level. RT depends on the physical volume and surface materials of a room. Large spaces, such as cathedrals and gym, usually have longer reverberation times and sound "lively" or sometimes "boomy." Small rooms, such as bedrooms and recording studios, are usually less reverberant and sound "dry" or "dead." Therefore acoustical needs in a classroom vary greatly from the acoustical needs in a cafeteria or gym.

School setting: refers to all learning environments and classrooms, including early childhood, elementary, secondary and post-secondary settings.

Signal-to-noise ratio (SNR): the relationship between the primary or desired auditory signal (e.g. educator's voice) and all other unwanted background sounds. With respect to classroom acoustics, SNR can be considered as the relative intensity of the information carrying the components of the speech signal versus unwanted noise. The more favorable the signal-to-noise ratio (SNR), the more intelligible the spoken message. A SNR of +15/20 dB or better is recognized as being necessary in the classroom.

Vocal load: Amount of vocal work over time, determined by vocal duration, intensity and frequency over time. (Titze, Svec & Popolo, 2003)

Voice loading: Stress exerted on vocal folds and the laryngeal mechanism due to sustained voice. Loading is exacerbated namely by variables such as ambient noise, level of vocal projection, dynamic and emotional extents, social context as well as acoustic environment. Similarly to repetitive strain injuries, voice loading may lead to vocal fatigue and/or mechanical or functional laryngeal injuries.

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