AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION

Acoustics in Educational Settings: Technical Report

ASHA Working Group on Classroom Acoustics

This technical report was developed by the American Speech-Language-Hearing Association's (ASHA's) Working Group on Classroom Acoustics. It was approved by ASHA's Executive Board in 2004. Members of the Working Group on Classroom Acoustics included Karen Anderson, Susan Brannen (vice president for professional practices in audiology, 2001–2003), Carl Crandell (co-chair), Peggy Nelson, Anne Seltz, Joseph Smaldino (co-chair), and Evelyn J. Williams (ex officio).

Introduction

Speaking and listening are the primary communication modes in most educational settings. Therefore noise levels and reverberation times (RTs) of these learning spaces should be such that speech produced by teachers, students, and others is intelligible. Unfortunately, many learning spaces have excessive noise (any unwanted sound inside or outside of the room) and RT (persistence of sound after the source itself stops). All students and teachers are negatively affected by noise and reverberation, but young students, English language learners, and students and teachers with hearing, language, or learning problems may be at a greater disadvantage. The acoustical properties of classrooms are often the "forgotten variables" in ensuring students' academic success, particularly for students with unique communication or educational needs (Crum & Matkin, 1976). Many U.S. classrooms do not meet preferred acoustic standards (e.g., Knecht, Nelson, Whitelaw, & Feth, 2002). Decades of research by audiologists, speech-language pathologists, acousticians, and others have documented the educational value of good acoustics and the detrimental effect of poor acoustics on students' auditory comprehension, learning, and behavior and teachers' vocal health.

For years, professionals, parents, organizations, and agencies have advocated for improved acoustics to ensure that all listeners can understand all talkers in a classroom. The 1990 passage of the Americans with Disabilities Act (ADA) intensified the focus on removing acoustical barriers in educational as well as other settings. Despite the ADA's accessibility guidelines, scientific research, and advocacy efforts of individuals interested in improving classroom acoustics, few educational settings provide appropriate acoustical environments. In 2002, the American National Standards Institute (ANSI) approved Standard S12.60 – 2002, "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools." Individuals involved in planning, renovating, and/or building schools now have acoustical performance criteria, design requirements, and guidelines to assist them in creating acoustically appropriate learning environments. Much of the research making up the scientific foundation of the standard emerged from the fields of audiology and speech-language pathology. Communication disorders specialists, all of whom live in a school district, can be strong advocates in the movement to improve classroom acoustics because they can interpret the research to others.

Numerous researchers have thoroughly documented the deleterious effects of excessive classroom noise and reverberation levels on speech-recognition ability and educational/social development (e.g., Bess & Tharpe, 1986; Blair, Peterson, & Viehweg, 1985; Crandell & Bess, 1986; Crandell & Smaldino, 2000; Crandell, 1992, 1993; Davis, Elfenbein, Schum, & Bentler, 1986; Finitzo-Hieber, 1988; Finitzo-Hieber & Tillman, 1978; Johnson, 2000; Leavitt & Flexer, 1991; Ross, 1978; Ross & Giolas, 1971; Shepard, Davis, Gorga, & Stelmachowicz, 1981; Smaldino & Flexer, 1991). Nevertheless, studies of the acoustical

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Associated documents: Position statement and guidelines

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conditions in unoccupied and occupied classrooms consistently reveal environments that exhibit excessive levels of noise and reverberation (Bess & McConnell, 1981; Crandell, 1993; Crandell & Bess, 1986; Crum, 1974; Finitzo-Hieber, 1988; Finitzo-Hieber & Tillman, 1978; Knecht et al., 2002; McCroskey & Devens, 1975; Neimoeller, 1968; Olsen, 1977, 1981, 1988).

The term "noise" (or variations—background noise, classroom noise, etc.) refers to any auditory disturbance that interferes with what a listener wants to hear (Finitzo-Hieber, 1988). The source(s) of the noise may or may not be within the classroom itself. Most classroom noise sources have been identified as (a) arising from outside the building and intruding through exterior walls and windows, (b) generated by heating / ventilating and air-conditioning (HVAC) systems, (c) intruding from hallways and adjacent rooms, and (d) generated from within the classroom by computers and appliances as well as by the children themselves. Sanders (1965) measured noise levels in 47 occupied and unoccupied classrooms in 15 buildings and noted mean occupied noise levels ranging from 52 dB (B) in classrooms for students with hearing loss to 60 dB (B) in kindergarten classrooms. Other studies have reported similar results (Crandell, 1992; Crandell & Smaldino, 1994; Nober & Nober, 1975; Paul, 1967). See Crandell and Smaldino (1992) for a review. Unoccupied noise levels were documented for 43 Ohio classrooms, ranging from 32 to 67 dB (A) (Knecht et al., 2002).

Whether internally or externally generated, the presence of high noise levels has led to relatively poor signal-to-noise ratios (SNRs) being measured in the classroom setting. The SNR is a direct comparison of the target signal level (often a teacher's voice) and the background noise level. For example, if a teacher's voice arrives at a child's desk at approximately 65 dB (A) and the general background noise level is 60 dB (A), the resulting SNR is +5. Depending on grade level and programming, reported SNRs have ranged from +5 to - 7 dB (Blair, 1977; Finitzo-Hieber, 1988; Markides, 1986; Paul, 1967; Sanders, 1965). In contrast, several investigators have noted that students with normal hearing require a +6 dB SNR for optimum auditory comprehension (see Crandell, 1992 and 1991). Furthermore, Johnson (2000) reported that consonant identification in noise and reverberation does not reach adult-like performance until the late teenage years, suggesting that good classroom acoustics are particularly important for young students. Students with special needs require even more favorable SNRs. The speech recognition ability of a child with even a minimal hearing loss (pure tone average of 15–25 dB HL) when compared to peers with normal hearing is 13% poorer at +6 SNR and 33% poorer at -6 SNR (Crandell, 1993). Students who are listening and learning in a non-native language make up a significant proportion of U.S. classrooms, and also require more favorable SNRs than children learning in their first language (e.g., Eriks-Brophy & Ayukawa, 2000; Mayo, Florentine, & Buus (1997); Soli & Sullivan, 1997, Crandell, 1996; Crandell & Smaldino, 1996; Hodgson & Montgomery, 1994). Students with learning disabilities, attention disorders, and other auditory disorders similarly show the need for very low noise levels and favorable SNRs (e.g., Cunningham, Nicol, Zecker, Bradlow, & Kraus, 2001; Flexer, Millen, & Brown, 1990; Gengel, 1971). Additional information about the educational implications of poor acoustics can be found in Nelson, Soli, & Seltz (2002) and in Nelson & Soli (2000).

The presence of a poor SNR is not the only variable that negatively affects speech recognition in the classroom. Interference caused by reverberation, or reflected sound energy, occurs as well. Reverberation time (RT) is the time differential between the cessation of the sound source and a measured decay of 60 dB. The amount of reverberation present in an enclosure increases linearly with room volume and is inversely related to the amount of sound-absorbing material present (See Beranek, 1954; Borrild, 1978; Knudsen & Harris, 1978; or ANSI, 2002, for specific measurement procedures for reverberation). The degradation of speech recognition by reverberation occurs through the masking of direct sound energy by the temporally delayed reflected energy (Bolt & MacDonald, 1949; Houtgast, 1981; Kurtovic, 1975; Lochner & Burger, 1964; Nabalek & Pickett, 1974a, b). Because vowel (low-frequency) sounds are more intense than consonant (high-frequency) sounds, reflected vowel phonemes tend to mask consonant information, particularly final consonants in words. Several researchers have noted that noise and reverberation combine synergistically to degrade speech recognition in classroom settings (Crandell & Bess, 1986; Crum, 1974; Nabelek, 1981; Nabelek & Pickett, 1974a, b; Klein, 1971; Peutz, 1971). This effect is caused by (a) reflected noise energy causing an increase in ambient noise level and (b) integration of background noise with reflected and delayed speech energy, which makes the resulting noise more uniform both temporally and spectrally. Measured RTs for unoccupied classrooms have been shown to range from 0.4 to 1.2 seconds (Bradley, 1986; Crandell, 1992; Finitzo-Hieber, 1988; Kodaras, 1960; Knecht et al., 2002; McCroskey & Devens, 1975; Olsen, 1988; Ross, 1978). Given that RTs longer than 0.5 seconds appear to degrade speech recognition for most listeners in an educational environment (Crandell & Bess, 1986; Crum, 1974; Finitzo-Hieber & Tillman, 1978; Neimoeller, 1968; Olsen, 1977, 1981), the above-noted RTs appear to be much too long for effective speech recognition.

Summary

Students of all ages and abilities, and their teachers, need appropriate classroom acoustics to communicate effectively in the classroom and other learning environments. The scientific literature has demonstrated that if an acoustic environment allows +15 dB SNR throughout the entire classroom generally, participants with normal hearing can hear well enough to receive the spoken message fully. The deleterious effect of poor acoustics on student comprehension and learning, especially students under age 15 and those with hearing and / or learning problems, is well documented.

This ASHA technical report and its companion documents, *Acoustics in Educational Settings: Position Statement* (ASHA, in press-a) and *Guidelines for Addressing Acoustics in Educational Settings* (ASHA, in press-b), can be used by ASHA professionals when they advocate for and work with schools, teachers, architects, contractors, state education agencies, and others in developing the best possible learning environments for all students. Guidelines for designing and building acoustically appropriate schools can be found in ANSI, 2002; Seep, Glosemeyer, Hulce, Linn, Aytar, & Coffeen, (2000); Siebein, Gold, Siebein, & Ermann, (2000); and ASHA, in press-b.

Research Directions

Future research is needed to document the benefit of good acoustics in general and for special student populations in particular. Because financial considerations are sometimes used to argue against creating good classroom acoustics, cost benefit studies are also needed. In particular, the open school concept, and its effect on acoustics and learning activities need to be carefully studied, preferably by a multidisciplinary research team. Cross-disciplinary research that includes audiologists and speech-language pathologists can influence architects, HVAC engineers, school administrators, builders, and material designers to support good classroom acoustics.

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