NOISE-CON 97
The Pennsylvania State University
University Park, Pennsylvania
1997 June 15-17

PILOT STUDIES OF SPEECH COMMUNICATION IN ELEMENTARY SCHOOL CLASSROOMS: LITERATURE REVIEW AND METHODS

Phillip Abbott, Carl C. Crandell, Martin A. Gold, M. Joyce Hasell, Christopher R. Herr, Hee Won Lee, Mitchell Lehde and Gary W. Siebein

University of Florida
P.O. Box 115702
Gainesville, FL 32611-5702

INTRODUCTION

This study investigates the dynamic, reciprocal interactions among young children, teachers, learning and communication in classroom settings. The acoustical qualities and architectural features of classrooms that contribute to the speech recognition of elementary school children will be measured to develop guidelines for improving classroom design. Numerous investigations [Crandell, Smaldino and Flexer (1995); Nabelek and Nabelek (1994)] have demonstrated that the acoustical environment in a classroom is an important variable contributing to the academic and psychosocial achievement of children. Additional studies have shown that children do not obtain adult-like abilities to perceive speech in noise or reverberation until approximately 15 years of age [Crandell (1992); Elliott (1979)]. Other studies have related a variety of new acoustical measures with speech intelligibility and the basic architectural features of rooms (Bradley, 1986). Despite these data, there have been few studies concerning classroom environments or acoustical qualities of rooms that are appropriate for young children.

Classrooms typically have both fixed features, such as walls, ceilings and floors; and non-fixed features, such as furniture and displays; that can be changed to accommodate a variety of long term and short term activities. Teaching and learning patterns are also dynamic. Several teachers may use the same space in a different way in a single day. Children's behavior is mediated by their own internal responses (emotional, cognitive, physiological and cultural background). Current speech recognition and acoustical measures do not fully reflect the dynamics of this situation. Therefore, this study combines methods from architectural acoustics, speech and hearing and environment/behavioral research in an attempt to holistically evaluate environmental qualities of classrooms and the speech recognition of children. This study uses Participatory Action Research (PAR) to identify concerns and research issues from teachers and students who use the rooms. How do teachers and students assess the quality of communication and learning in the rooms? Do they relate these perceived qualities to acoustical attributes or architectural features of the rooms? How do instructional techniques compensate for or overcome poor environmental qualities? How important are communication and the acoustical qualities of the rooms relative to other aspects of the classroom

environment? How are these environmental qualities linked to the behavior and learning of the students? The answers to these questions will allow the research to identify parameters for better classrooms.

Speech Perception in Children: Effects of the Acoustical Environment. A number of populations of children with normal-hearing sensitivity have been identified who experience greater speech-perception difficulties in the classroom environment than has traditionally been suspected (ASHA, 1995; Crandell, 1991; Crandell & Bess, 1986; Crandell, Smaldino, & Flexer, 1995; Nabelek & Nabelek, 1994). These "normal-hearing" populations include young, pediatric listeners (<13-15 years' old); children for whom English is a second language; children with developmental delays and/or attention deficits; children with learning-disabilities; and children with a number of minor auditory and neural problems. The acoustical environment of a classroom has also been identified as a critical factor in the psychoeducational and psychosocial achievement of children with hearing impairment. Inappropriate levels of classroom noise and/or reverberation can deleteriously affect not only speech perception, but also reading/spelling ability, behavior, attention, concentration, and academic achievement in children with even minimal degrees of sensorineural hearing loss (SNHL) (e.g., Crandell, 1991; Crandell & Bess, 1986; Crandell, Smaldino, & Flexer,1995; Davis, Elfenbein, Schum, & Bentler, 1986; Finitzo-Hieber & Tillman, 1978; Ross, 1978).

Speech Perception of Children with Normal-Hearing Sensitivity in The Classroom. Numerous investigators have demonstrated that children with normal-hearing sensitivity require higher signal-to-noise ratios (SNRs) and shorter reverberation times (RTs) than adult normal hearers to achieve equivalent perception scores (Crandell, 1992; Crandell, Smaldino, & Flexer,1995; Elliott, 1979; Nabelek & Nabelek, 1994). Adult-like performance on perception tasks in noise or reverberation is generally not reached until the child reaches approximately 13 - 15 years of age. Based on these data, it is reasonable to hypothesize that commonly-reported levels of classroom noise and reverberation can deleteriously affect the speech perception of younger children with normal-hearing sensitivity. Finitzo-Hieber & Tillman (1978) found that children with normal hearing generally obtained extremely poor speech-perception scores in classrooms. For example, in a relatively good classroom listening environment (SNR = +6 dB; RT = 0.4 second), children with normal hearing were able to recognize only 71% of the stimuli. In a poor, but commonly-reported classroom environment (SNR = 0 dB; RT = 1.2 second), speech-perception scores were reduced to less than 30%.

Classroom Acoustics and Psychoeducational Achievement of Children with Normal Hearing. It is important to note that in addition to reductions in speech perception, classroom noise can also compromise psychoeducational and psychosocial achievement in children with normal hearing (Green, Pasternak, & Shore, 1982; Koszarny, 1978). Stated otherwise, noise has been demonstrated to adversely affect academic performance, reading and spelling skills, concentration, attention, and student behavior. Koszarny (1981) found that noise levels tend to more seriously affect concentration and attention in children with lower IQS and/or high anxiety levels. Green, Pasternak, and Shore (1982) found that classroom noise alone accounted for approximately 50-75% of the variance in reading delays of one year or more in elementary school children.

Impulse response measurements and the importance of early sound reflections. The development of acoustic measures based on impulse response test techniques and the subsequent psychoacoustic investigations on the importance of individual sound reflections to the perception of

speech and music in rooms have resulted in the understanding of three major parts to the sound build-up and decay processes in rooms. The direct sound is followed shortly by early reflections from primary room surfaces which are heard as increasing the loudness and clarity of the direct sound. These early reflections have been shown to increase speech recognition in adult listeners even in the presence of reverberation. The reverberant decay does not begin until sometime after this period of early reflections. The contribution of these early reflections is essential in the recognition of speech as reflected by acoustical measures such as Clarity Index (C_{50} and C_{80}); Useful to detrimental energy ratios such as U_{80}; Speech Transmission Index (STI and RASTI)(Bradley, 1986).

It has been shown that acoustical measures derived from impulse rsponse tests will vary with source and listener locations even in relatively small rooms. Chiang (1994) has shown that these variations are due to the contributions of the architectural design features of concert halls, theaters and lecture halls. It has been suggested by Ando that the intelligibilty of speech may be related to binaural measures such as interaural cross correlations (IACC) indicating some relationship to early reflections and the relative diffusion of the reverberant sound field in the room.

METHODS

A hybrid approach will be used in the project involving methods from several disciplines.

Participatory Action Research (PAR). A form of Whyte's (1991) "participatory action research" (PAR) will be used to identify communication, learning, teaching, architectural and acoustical issues from the perspectives of the teachers and students. This approach is widely used in the appraisal of qualitative aspects of environments to assist in programming new facilities and post occupancy evaluation of existing buildings. It is anticipated that the complex interactions among the physical environment of the classrooms, the teaching techniques of the faculty, the behavior of the students and the quality of the learning that occurs in the rooms can be identified using these methods. Once the broad range of issues are identified, a series of case studies will be conducted in actual elementary schools to gather the data for the project.

PAR presumes a partnership between researchers and participants including educational administrators, teachers, parents and children, to assess the hearing capacity of children, and to determine how well classrooms with particular acoustical qualities support both teaching and learning. Preliminary studies confirm that administrators and teachers share an intense desire to know more about the physical characteristics of classroom environments that could improve their teaching. Visual techniques will be mixed with interviews to increase the validity of respondents' descriptions of their physical environment (Sanoff 1991; 1994; Hasell et al 1993). For example, having the teachers describe their concerns enabled the identification of both the untapped potentials and undiscovered problems in classrooms in the "eyes of the users". Sanoff suggests that classroom environments may be assessed according to how they are perceived and used by the students and teacher. The assessment strategy consists of descriptive statements based on teacher's and student's needs and classroom performance expressed as operational definitions of privacy, personal space, personal expression, social grouping, personal meaning, and participation. Sanoff and others have also used qualitative techniques to allow children, teachers, parents, and administrators to describe in their own words their daily conditions and preferences for better places in which to learn.

While acoustical measurements and speech recognition tests made in classrooms typically place a sound source in the front, center of the rooms as though a teacher is lecturing to students seated in the room, preliminary PAR studies have shown that this is only one of several modes of instruction actually used in elementary school classrooms, and it might not be the predominant one! The teachers were frequently observed walking through the aisles in the class room while they spoke rather than standing at the blackboard. This dynamic style minimizes the speaker to listener distance and thus, increases the loudness and signal to noise ratio of sounds for many students. Many teachers were observed in a reading circle where a small group of students sat in close proximity to the teacher, each one reading a passage in turn. The other students worked in self directed study at several activity "centers" under the supervision of an aide or a parent volunteer. Teachers, aides and volunteers also spent a considerable amount of time talking to individual students at their desks to review work in progress. The hearing of speech and dynamics of communication are much different for these activities than for a lecture. There are also different acoustical and architectural design challenges posed by the different teaching methods. The PAR studies will identify many of these situations that occur during typical instruction in a variety of actual classrooms and grade levels to understand more completely what the acoustical components of the research should focus on.

Selection of rooms and students to use in the case studies. Once the major issues have been identified through the PAR studies, a series of rooms and students will be selected for case studies. There is interest in studying different age groups. Initially the study will focus on 3 groups: Pre-kindergarten to grade 1; grades 2-3; and grades 4-6. Further studies will include middle school, high school; and college students as well as adults. Children will initially be selected and screened for normal hearing. Follow-up work will address these issues relative to the special populations noted above.

Schools will be chosen to gain representative samples of different socio-economic classes, races and genders in the students. This is important to understand the contribution these factors may have on the learning and communication issues of interest in the study. The classrooms will be chosen in several localities including urban, suburban and rural areas. Buildings constructed at different times in different conditions with different acoustical qualities will also be chosen. At the present time, two county school districts are cooperating with the research team in this regard.

Detailed inventory of the architectural characteristics of the rooms. Chiang (1994) and Carvalho (1996) have shown that the detailed architectural features of rooms are related to both acoustical measures made in the rooms and the qualities of sounds heard in concert halls and churches respectively. It is reasonable to assume that this thesis can be extended to class rooms. Therefore, the architectural features such as dimensions, volume, seat locations, materials, shape, furnishings, etc. will be recorded in detail.

Acoustical measurements. A series of acoustical measurements will be made at multiple locations in each class room from multiple source locations using the impulse response technique. A TEF analyzer, JBL's Smaart system and two custom systems are available for this work. Acoustical measures of reverberation time, early reverberation time, early to late energy ratios, loudness (or relative strength), Alcons, speech transmission index, background noise levels and signal-to-noise ratios as well as binaural measures will be made to document the acoustical conditions.

Speech recognition tests. Speech recognition of children in the rooms will be assessed by nonsense syllables and monosyllabic word tests in the classroom and in the laboratory. The stimuli will be presented in the classroom via a calibrated digital tape recorder (83 dB SPL at 3 inches) through a loudspeaker that closely approximates the directional characteristics of the human voice (Q=2.5). The source will be placed at the front of the classroom and at other locations identified in the PAR studies where the teacher might frequently stand. Monosyllabic nonsense stimuli will be used because (1) practice/learning effects are minimal; (2) children as young as 5 years of age can perform this task; (3) closed set testing responses can be utilized; and (4) consonant confusion matrices can be produced from the data. The child's task will be to circle the correct choice on an answer sheet. Responses from children with known hearing impairment, learning disability, or visual disability will be excluded from this aspect of the experiment as will responses from any child for whom English is a second language. On each speech-recognition form, the location/position of the child in the room (distance from the speaker, position in the classroom, etc.) will be documented. All students will be asked to remain as quiet as possible during the recognition testing. Speech-recognition data will be obtained from a representative sample of children, aged 5-15 years.

Learning qualities tests. A survey instrument and participatory action techniques will be used to assess acoustic and non-acoustic factors that might affect speech recognition and learning.

CONCLUSIONS

Relations among the teaching methods, speech recognition measures, acoustical measurements, and the architectural design features of the classrooms will be examined. The comments on the qualities of the learning environments, the acoustical tests and the actual communication processes that occur in daily teaching will be analyzed to identify possible relationships. The hope is that acoustical qualities in addition to speech intelligibility or recognition can be found that reflect some of the primary attributes of teaching, learning and communication in classrooms. Data obtained will be discussed in view of developing appropriate classroom acoustics for elementary school children.

REFERENCES

Argyris, Chris & Donald A. Schon. 1991. "Participatory Action Research and Action Science Compared: A Commentary." pp 85-96 in Whyte, William Foote. 1991, ed. *Participatory Action Research.* Newbury Park: Sage.

_____.1974. *Theory in Practice.* San Francisco: Jossey Bass.

ASHA. (1995). Guidelines for Acoustics in Educational Environments. *American Speech-Language and Hearing Association*, 37, Suppl. 14, 15-19.

Bradley, John S. (1986) Speech Intelligibility Studies in Classrooms. *JASA*, 80 (3), pp. 846-854.

Carvalho, Antonio P.O. (1996). Analysis of Subjective Acoustic Measures and Speech Intelligibility in Portuguese Churches. A paper presented at the Acoustical Society of America meeting, Indianapolis, IN, May, 1996.

Chiang, Wei-hwa (1994). Effects of Architectural Parameters on Six Acoustical Measurements in Auditoria. A Doctoral Dissertation at the University of Florida, Gainesville, Florida.

Crandell, C. (1991). Classroom acoustics for normal-hearing children: Implications for rehabilitation. Educational Audiology Monograph, 2(1), 18-38.

Crandell, C., & Bess, F. (1986). Speech recognition of children in a "typical" classroom setting. *ASHA*, 29, 87.

Crandell, C., Smaldino, J., & Flexer, C. (1995). *Sound Field FM Amplification: Theory and Practical Applications*. Singular Press. Los Angles, CA.

Davis, J., Elfenbein, J., Schum, R., & Bentler R. (1986). Effects of mild and moderate hearing impairments on language, educational, and psychosocial behavior of children. *Journal of Speech and Hearing Disorders*, 51, 53-62.

Elliott, L. (1979). Performance of children aged 9 to 17 years on a test of speech intelligibility in noise using sentence material with controlled word predictability. *Journal of the Acoustical Society of America*, 66, 651-653.

Finitzo-Hieber, T. & Tillman, T. (1978). Room acoustics effects on monosyllabic word discrimination ability for normal and hearing-impaired children. *Journal of Speech and Hearing Research*, 21, 440-458.

Green, K., Pasternak, B., & Shore, B. (1982). Effects of aircraft noise on reading ability of schools age children. *Archives of Environmental Health*, 37, 24-31.

Hasell, M. Joyce, Peatross, Frieda D. & Christine A. Bono-Boyett. 1993. Gender choice and domestic space: Preferences for kitchens in married households. *Journal of Architectural And Planning Research. 10* (1), 1-22.

Koszarny, Z. (1978). Effects of aircraft noise on the mental functions of school children. *Archives of Acoustics*, 385-86

Nabelek, A. & Nabelek, I. (1994). Room acoustics and speech perception. In J. Katz (ed.), *Handbook of Clinical Audiology, 4th ed.* Williams & Wilkins: Baltimore.

Ross, M. (1978). Classroom acoustics and speech intelligibility. In J. Katz (Ed.), *Handbook of Clinical Audiology*. Williams and Wilkins: Baltimore.

Sanoff, Henry. 1991. *Visual research methods in design*. New York : Van Nostrand Reinhold.

_____. 1994. *School Design* New York: Van Nostrand Reinhold.

Whyte, William Foote. (1991), ed. *Participatory Action Research.* Newbury Park: Sage.