Acoustic Conditions in Classrooms for the Hearing Impaired in Nicaragua

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Acoustic conditions in 18 Nicaraguan classrooms for children with hearing impairments were examined to determine whether they met published recommendations regarding overall noise levels, reverberation, and signal-to-noise ratios. The classrooms were constructed of hard, reflective surfaces with little absorptive material. Both unoccupied and occupied noise levels exceeded published recommendations. Reverberation times were longer than those recommended and were not consistent across frequencies. Only 18% of the classrooms had signal-to-noise levels within the limits recommended for children with hearing impairments. Children wearing hearing aids would be expected to have difficulty understanding acoustic stimuli in these classrooms.

Although an individual's ability to perceive sound through the ears is obviously the basis for aural learning, the acoustic conditions in which that learning takes place determine whether maximal use of the auditory sense is possible. In spaces designated as classrooms, it is imperative that the design and composition of the rooms maximize speech intelligibility and that these spaces provide an atmosphere in which concentrated mental activity can take place.

Speech intelligibility is a measure of how understandable or decodable a par-

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ticular segment of speech is within a certain context. Intelligibility is influenced by language factors, the speaker's production, and the acoustic conditions in which the message is received (Berg, 1993; Peutz, 1971). Acoustic factors include the amount and configuration of reflected sounds or absorption present, as well as the noise level in the environment. The overall noise level is important, but the noise spectrum and signal-to-noise (S/N) ratio also influence intelligibility.

In classrooms, language factors are usually known and controlled. Teachers commonly adapt the sentence length, vocabulary, and grammatical complexity of their language to the group with which they are working (Silliman & Wilkinson, 1991). Individual speech characteristics are accessible to modification. Acoustic factors, however, are rarely amenable to change by teachers, yet their impact upon the intelligibility of the teacher's speech is profound.

Beyond concern about how well or how poorly the speech used within a classroom is received, attention must be given to ensuring that the classroom provides an atmosphere in which concentrated mental activity can take place. Unlike vision, which can be voluntarily interrupted by the closing of the eyes, audition is "on" and processing input at all times, even when a person is asleep. A noisy acoustic environment in a classroom disrupts mental concentration and makes the development of habits of mental concentration difficult. Where mental concentration is absent, little learning will take place (Berg, 1993).

The acoustic needs mentioned above relate to all students in all classrooms. However, people with compromised hearing require even better acoustic conditions than do those with normal hearing if they are to decode acoustic input (Crandell, Smaldino, & Flexer, 1995). To derive meaning from speech in a classroom, children with hearing impairments need to be listening within the direct sound field, face-to-face, and in conditions with a higher S/N ratio and lower reverberation time than is necessary for their normally-hearing classmates (Crandell & Smaldino, 1994). It has been shown for adults (Nabelek & Pickett, 1974) and for children (Finitzo-Hieber & Tillman, 1978) that, when ambient noise and reverberation are increased, the combination causes even greater deterioration than is found under a single condition.

CONDITIONS IN NICARAGUA

Environment

While the need to maximize acoustic learning environments has received increasing attention in the literature (e.g., American Speech-Language-Hearing Association [ASHA], 1995; Berg, 1993; Berg, Blair, & Benson, 1996; Crandell & Smaldino, 1994; Crandell et al., 1995; etc.), to date, little attention has been paid to these needs in the construction and maintenance of classrooms in Nicaragua. In three papers written recently about the recommended architectural standards and needs of classrooms in Nicaragua, acoustic considerations were not mentioned at all (see Arguello Carazo, 1996a, 1996b; Pacheco Pilon, 1996b). In a fourth paper, the need to search for sites with low traffic noise was noted, but acoustic factors internal to the classroom (internal noise, S/N ratio, reverberation) were not included (see Pacheco Pilon, 1996a).

Though the need for a good acoustic environment remains the same whether one is in North America, Europe, or Latin America, the recommendations made for design and modifications of classrooms in North America and Europe are often not applicable to conditions found in countries such as Nicaragua. Climatic conditions and social interaction differ to an extent that conclusions reached about classrooms in other countries cannot be applied indiscriminately to conditions in countries such as Nicaragua. The purpose of this study was to describe the acoustic conditions in classrooms for children with hearing impairments in Nicaragua as a preliminary step toward formulating appropriate solutions and modifications for classrooms in countries with similar circumstances.

The Nicaraguan Special Education System

Although schooling for children with hearing losses has been available in Nicaragua since 1946, it was not until the mid-1970s that such education became available outside of Managua, the capital. In 1979, the Sandinista Revolutionary philosophy advocating universal education resulted in a policy decision to place at least one special education school in each of the 15 *departamentos* (states). Thus the number of schools offering special education increased from 7 in 1979 to 22 by 1982 (Convenio MED-CONESCAL, 1980). Special education schools serve children with mental, vision, hearing, and motoric handicaps with classrooms grouped according to disability. When there is more than one classroom for a given disability, groups are according to grade.

Not all schools have classrooms for all disabilities. Classrooms for children with mental retardation are the most common (75% of the total), followed by those for children with hearing impairments (20% of the total), with relatively few classrooms for children with vision or motoric impairments. In 1997, there were 1,904 children enrolled in all special education classrooms throughout the Republic of Nicaragua (Ministerio de Educación, 1997b). Five hundred of these students were enrolled in 55 classrooms for children with hearing impairments *(aulas de audición)* in 18 schools (Ministerio de Educación, 1997a). Fifteen of the schools with *audición* classrooms are in the Pacific zone, one is in the Central zone *(Juigalpa),* and two are on the Atlantic Coast *(Bluefields* and *Puerto Cabezas).*

Class size in special education classrooms is small, averaging fewer than 10 students to a teacher, a significant difference from the regular public education classes in Nicaragua in which primary classes of 50-60 students per teacher are common. Children with mild hearing impairments rarely are included in *audi-*

ción classrooms. Analysis of audiograms of the children enrolled in *Escuela Melania Morales* in *Managua*, where 206 of the 500 students enrolled in *audición* are located, revealed no audiograms with pure-tone averages better than 60 dB HL in either ear. Fifteen percent of the children had PTAs[1] in the better ear between 60 and 80 dB HL, 26% had PTAs of 80-100 dB HL, 32% had PTAs between 100 and 109 dB HL, and 27% had profound losses with PTAs exceeding 110 dB HL.

Hearing Aid Use

In general, fewer than 10% of those enrolled in classrooms for children with hearing impairments use hearing aids during classroom instruction. A survey of hearing aid use among the 156 *audición* students present on June 10, 1997 at the *Escuela Melania Morales* revealed only 3% of the children were wearing hearing aids, and less than 1% had functioning hearing aids. According to the teachers, the hearing aid use for that day was typical, with one preschool teacher stating that she discouraged parents from sending their children to her class wearing hearing aids because "when the children play, the aid might get broken, and then the parents would blame me." This same pattern of hearing aid use was found throughout this study at the other schools with classrooms for children with hearing impairments. Since 1991 the *Centro de Asesoramiento Audiológico* run by *Los Pipitos* (the association of parents of handicapped children) has begun an early language stimulation program (for children 0-3 years), in which use of binaural amplification for children with hearing impairments is emphasized. It is possible that with their influence, use of hearing aids in special education classrooms will increase in the future, as the children served in that preschool program enter the elementary grades.

Architecture

Traditional architectural patterns, climatic needs, and geologic considerations have influenced how Nicaraguan schools have been built and thus have influenced the acoustic conditions in the resulting classrooms.

Most schools in Nicaragua are built in a "pavilion" style in which multiple classrooms are placed side by side in rows. These rows are either placed parallel to each other or in a square around a courtyard or *plaza cívica.* This form of construction provides acoustic pathways for noise to pass from one classroom to another, either through the common walls or through the open windows and doors. The *Escuela Hogar* in *Ciudad Darío* is one of the few special education schools not built in a pavilion style but rather in a "cluster" style. Unfortunately, the doors of all of the classrooms open onto a common area, and all of its classrooms

[1]Pure-tone averages are calculated as the average thresholds for the frequencies 500, 1000, 2000, and 4000 Hz. A lack of response at the limits of the audiometer was assigned a value of 115 dB HL for purposes of calculation.

are united by a system of corridors that add reverberation. The resulting amplified sound is directed back into each of the classrooms through the windows opened for ventilation.

Climate

Climatic conditions in Nicaragua are such that ventilation and the free circulation of air are crucial considerations. During the academic year (March to November), the climate of Nicaragua is hot and humid. Ventilation is provided by opening windows and doors for cross-ventilation. In some schools the walls between classrooms are not built to meet the roof, but instead a space is left for air to circulate. When those classrooms are in use, isolation between classrooms is minimal because the airborne noise from one classroom is transmitted through the gap between the wall and the roof directly into the adjacent classroom. Classroom windows and doors are closed only when not in use. The incidence of broken window panes is high, and in many instances there are no doors to the classrooms, only metal bars for security. Beyond allowing the sounds from neighboring classrooms to enter as ambient noise, these ventilation systems provide entrance for noise from corridors and courtyards within the schools, and for environmental noise such as traffic or loud radio music.

In a climate in which water is scarce for much of the year and expensive year round, little use has been made in the special education schools of the sound isolative effects of landscaping. While most schools have a few ornamental plants, there is no special education school with a planned use of trees and shrubbery to provide acoustic absorption of playground or traffic noise. Unfortunately, on the sides of the schools most affected by traffic noise, there is no space left to place the shrubbery which could act as insulators for the traffic noise.

The fact that the climate of Nicaragua has two main divisions, the dry season (November to May) and the rainy season (May to October), means that building materials must be resistant to water damage and dust. Carpet, for example, which is likely to be ruined both by water damage and excessive dust, is never found as an absorptive material in Nicaraguan *audición* classrooms. Further, the desperate economic situation of the country results in imported materials (acoustic tile) rarely being used and locally-produced materials (concrete floor tiles, concrete blocks) are preferred.

Geology

Nicaragua lies within an earthquake belt, and every year experiences many minor seismic shocks, as well as having a history of major earthquakes (e.g., 1931, 1972). Architectural standards thus require use of materials and construction forms that best withstand seismic eruptions. Some form of reinforced walls (poured reinforced concrete blocks) are typical, with hard tile floors and galvanized metal roofs being usual.

RECOMMENDED ACOUSTIC CONDITIONS IN CLASSROOMS FOR CHILDREN WITH HEARING LOSS

Unoccupied and Occupied Noise Levels

The average level of sound in classrooms is typically measured under two conditions: while unoccupied and while the students and teacher are present (Berg, 1993). In other published studies, unoccupied noise levels included noise generated by heating or air conditioning systems, but no special education school in Nicaragua has heating or air conditioning in its classrooms. More intrusive in Nicaragua is the noise generated outside of the classroom which enters and becomes ambient noise during the teaching sessions. Occupied noise levels include the noise measured in unoccupied levels with the addition of noise generated by the persons within the room. In classrooms this is typically students talking, whispering, shouting, dropping books, scraping feet, and moving chairs and desks.

Although adults can tolerate noise levels of 50 dBA, children should have quieter conditions when engaged in mental activity requiring concentration (Pfeifer, 1993, p. 63). Webster and Snell (1983) found that the speech recognition scores of normally-hearing children appeared to be minimally affected by noise levels under 65 dBA, but children with mild hearing losses showed detrimental effects when the noise level exceeded 55 dBA, and children with moderate to severe hearing losses showed significant interference when noise levels exceeded 50 dBA.

Because all of the children in the *audición* classrooms have at least a moderate hearing loss, the desirable target chosen for this study was an occupied level of 50 dBA in an occupied room. To meet an occupied noise level of 50 dBA, it is necessary to have an unoccupied level at least 10 dB quieter (Berg, 1993).[2]

Reverberation Time

Reverberation is the prolonged or repeated reflection of sound, which can be quantified as RT (reverberation time), defined as the time it takes for a sound to decay 60 dB from its original intensity (Nabelek & Mason, 1981). The RT depends upon the absorption characteristics of a particular room. When RTs are high, the vowels of speech, which tend to have higher energy, mask the low intensity consonants and thus degrade speech intelligibility.

It has been recommended that the RT_{avg} (average of RTs measured at 500 Hz, 1000 Hz, and 2000 Hz) not exceed 0.5 s in classrooms for normally-hearing children or 0.3 s in classrooms for children with hearing impairments (Berg et al., 1996). The ASHA subcommittee's recommendation of RT no greater than 0.4 s

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[2]The ASHA Subcommittee on Acoustics in Educational Settings recommends that unoccupied levels not exceed 30 dBA (ASHA, 1995). These levels were not used because, given previous knowledge of the conditions, they seemed unrealistically strict.

(ASHA, 1995) is essentially a compromise between these two levels. Furthermore, RTs should be uniform across the spectrum. If the RTs at lower frequencies are longer than the RTs at higher frequencies, the masking of high-frequency consonants by the low-frequency vowels will occur (Nabelek, Letowski, & Tucker, 1989). The reverberation times for a given room were judged uniform if the RT at one frequency did not differ more than 0.1 s from the RT at adjacent frequencies.

S/N Ratio

The ratio (in dB) between the desired signal, which in classrooms is typically the teacher's voice, and the level of ambient noise is known as the S/N ratio. Normally-hearing children can tolerate low S/N ratios and still derive some understanding of the acoustic signal, but children with hearing impairments listening through hearing aids cannot (Nabelek & Mason, 1981). Desirable S/N ratios for children using hearing aids would be at least +15 dB (Finitzo-Hieber, 1988). This is hard to attain, and other experts in classroom acoustics have recommended that classrooms for children with hearing impairments have occupied noise levels of 50 dBA or less, unoccupied levels less than 40 dBA, and that the S/N ratio be at least +10 (Berg, 1993). The acceptable target for this study was the less stringent +10 S/N ratio.

The first step in determining whether acoustical conditions in *audición* classrooms in Nicaragua provide an adequate environment for learning was to document the present situation. Measurements were made in a representative classroom in each of the 18 schools in the Republic which have classes for children with hearing impairments. Those measurements were compared to the recommended norms.

METHOD

The 20 special education schools administered by the Ministry of Education in the Republic of Nicaragua reported in February 1997 to contain at least one classroom dedicated to the instruction of deaf or hard-of-hearing students were evaluated. The relevant classrooms in two schools were later found to have been closed. Thus, 18 sites were included in the present study. Because many of the schools had only one classroom for children with hearing impairments (e.g., *Rivas, El Viejo, Matagalpa, Nagarote,* and *Ocotal*) and the logistics of travel in Nicaragua meant that measurement time was limited, one classroom at each school was evaluated. When there was more than one classroom for *audición* students, the class with the youngest children was evaluated. Occupied classroom measurements were taken during normal classroom instruction, and unoccupied measurements were taken when the school was not in session.

The study consisted of two parts: (a) descriptive information about the physical conditions, obtained through observations and interviews, and (b) noise measurements conducted on site. A questionnaire was used to obtain information about the state of the physical plant, the type of construction materials used, and the location of the school near noise sources. The measurements included room dimensions, and various acoustic measurements, which were taken with a hand-held Quest 2700 Impulse Sound Level Meter and a Goldline GL60 reverberation meter. Both occupied and unoccupied noise levels on the dBA scale and within-octave bands were measured, as was estimation of S/N ratio in the occupied classroom.

The data reported are averages of at least six individual measurements and usually of 36 measurements taken with the hand-held sound level meter, set first to the *A* scale, and then measured in octave bands. Occupied and unoccupied levels and S/N ratios were obtained by making six measurements at 10-s intervals in each of six different positions within the classrooms and averaging the results. The positions chosen were center of the room, position where the teacher normally stands, and positions approximately 1 m from the center of the room to the north, south, east, and west.

The levels used to calculate signal in the S/N ratio were obtained by having the teacher read a paragraph aloud with the sound level meter located at 0° azimuth at 1 m, with samples taken at 10-s intervals over a 2-min period. The samples were then averaged to obtain the average level of signal. This level was compared to the average occupied noise level of the classroom to obtain an approximation of the S/N ratio in the classroom.

The reverberation samples were taken in three positions: with the stimulus delivered at 0° azimuth 1 m from the reverberation meter set in the middle of the room, with the stimulus delivered at 1 m to the right of the original position, and at 1 m to the left of the original position. The three readings were averaged. Measurements were taken for RT at 500, 1000, and 2000 Hz and then averaged to provide the RT_{avg}, which is the reported value. The stimulus was a blown-up balloon popped with a straight pin.

RESULTS

Physical Conditions

A summary of the physical condition of each school is shown in Table 1. Table 2 contains a summary of the acoustic measurements performed at each school. The 18 schools were given an overall rating of good, fair, or poor relative to their overall physical condition. Half of the schools were judged to be in good condition, while five (28%) were rated as fair and four (22%) were rated in poor condition. The schools judged to be in good condition had complete window panes, closeable doors, non-deteriorated ceiling panels, and complete floor tiles. Schools judged to be in fair condition showed some deterioration in windows, doors, ceiling, or floor, but the damage was not present in all categories. Schools

Table 1

Summary of the Physical Conditions Found in Each of the Schools

Location	Condition	Walls	Roof	Ceiling?	Floor	Windows
1. Chinandega	good	brick	Zinc[a]	no	concrete tile	glass slats
2. Ciudad Darío	good	brick	Nicalit[b]	yes (plywood)	concrete tile	glass slats
3. El Viejo	good	concrete block	Zinc	no	concrete tile	glass slats
4. Estelí	good	concrete block	Nicalit	yes (plywood)	concrete tile	glass slats
5. Granada	good	brick	Zinc	yes (poroplast)[c]	concrete tile	glass slats
6. Jinotega	good	brick	Zinc	no	concrete tile	wooden slats
7. Matagalpa	good	brick	Zinc	no	concrete tile	glass slats
8. Puerto Cabezas	good	concrete block	Zinc	yes (plywood)	concrete tile	decorative concrete block
9. Rivas	good	brick	Zinc	no	concrete tile	glass slats
10. Bluefields	fair	concrete block	Zinc	no	concrete tile	glass slats
11. Jinotepe	fair	concrete block	Zinc	no	concrete tile	windows with panes
12. Juigalpa	fair	pre-fab concrete	Zinc	no	concrete tile	glass slats
13. León	fair	pre-fab concrete	Nicalit	no	concrete tile	glass slats
14. Nagarote	average	brick	Zinc	no	concrete tile	glass slats
15. Diriamba	poor	adobe	Teja	no	concrete tile	netting only
16. Managua	poor	brick	Nicalit	yes (plywood)	concrete tile	glass slats
17. Masaya	poor	concrete block	Zinc	no	poured concrete	netting only
18. Ocotal	poor	concrete block	Zinc	no	poured concrete	glass slats

[a]Although commonly referred to as "zinc," these are actually sheets of galvanized steel. [b]Brand name for sheets of a prefabricated fiber/concrete mixture. [c]Another brand name for prefabricated sheets of fiber/concrete (different fiber mixture).

Table 2

Summary of Acoustic Measurements Made at Each School

Location	Overall unoccupied level (dBA)	Overall occupied level (dBA)	RT_{avg} (average of RT at 500, 1000, 2000 Hz)	Average signal (dBA)	Average noise (dBA)	S/N ratio
1. Chinandega	47.7	70.8	0.7	61.3	67.9	- 6.9
2. Ciudad Darío	46.9	74.9	1.5	65.1	78.9	-13.8
3. El Viejo	49.5	73.1	0.8	78.0	77.8	+ 0.2
4. Estelí	**40.7**	60.5	0.9	73.6	62.06	**+11.5**
5. Granada	50.1	59.0	1.3	75.5	59.7	**+15.7**
6. Jinotega	46.5	63.9	1.3	70.5	70.95	- 0.4
7. Matagalpa	50.4	61.0	1.7	70.5	60.5	+ 9.9
8. Puerto Cabezas	49.0	64.7	1.8	63.4	61.8	- 1.6
9. Rivas	52.5	61.3	1.5	64.5	64.9	- 0.3
10. Bluefields	50.7	61.8	0.9	75.4	67.8	+ 7.5
11. Jinotepe	56.7	67.4	1.1	70.6	68.2	+ 2.3
12. Juigalpa	48.6	69.4	1.3	73.2	67.4	+ 5.7
13. León	50.8	71.3	1.1	66.7	71.7	- 4.9
14. Nagarote	68.5	69.4	0.7	77.8	70.1	+ 7.6
15. Diriamba	52.1	69.5	2.3	65.2	71.2	- 5.9
16. Managua	46.0	72.2	1.0	66.0	74.3	- 8.3
17. Masaya	48.1	71.2	1.1	68.4	70.8	- 2.4
18. Ocotal	**38.1**	56.5	1.0	69.9	53.5	**+16.3**
M	49.6	66.5	1.22	69.7	67.5	1.9
SD	6.3	5.5	0.42	5.0	6.6	8.4
Minimum	38.1	56.5	0.7	51.3	53.5	-13.8
Maximum	68.5	74.9	2.3	78.0	78.9	+16.3

Note. Results listed in bold mean that the measurement met the recommended level.

in poor condition had a significant number or all of the window panes missing, no closeable door, water-damaged ceiling panels, and broken floor tiles.

Materials

All of the schools had classrooms with hard, flat surfaces on at least five of six surfaces. Seven out of 18 schools (39%) had walls built of bricks, while eight (44%) had concrete block walls. Two (11%) had pre-fabricated concrete slabs for walls, and one (6%) had walls made of adobe. Thirteen (72%) had a finishing applied to the walls, and 15 (83%) had painted walls. Fifteen (83%) had concrete tiles as flooring, and three (17%) had poured concrete floors. Galvanized steel was the typical roofing material in nine cases (50%), while eight (44%) had a concrete fiberboard roof. One *(Diriamba),* the oldest school, had a roof made of clay tiles. Only six schools (33%) had ceilings, and all of these consisted of wooden panels which were hard and flat. No absorptive treatment of walls or floors was observed. The decorations on the walls all tended to be smooth and flat which contributed minimally to any absorption in the room.

Within the classroom, significant portions of at least two walls were taken up with large blackboards made from either concrete or plywood, surfaces that were flat and hard. Windows were mainly moveable glass slats (83%), although one school had windows with glass panes. Two schools only had metal netting over the windows, to keep out thieves. In these last cases there was no external noise attenuation possible. Ventilation was generally provided by open windows and doors, and in addition, a few schools had walls that did not reach to the roof, allowing circulation of air in the breach between walls and roof.

Location in the Community

While some special education schools were located in more isolated sites, away from city traffic, two (11%) were located next to busy market areas, five (28%) at busy bus stops, six (33%) on main arterials, five (28%) next to churches, and four (22%) next to restaurants. All of these provided significant levels of external noise for the schools.

Unoccupied Noise Levels

Only two schools *(Estelí* and *Ocotal)* were able to meet unoccupied levels of 40 dBA or less. Eight of the schools (44%) had unoccupied levels between 40 and 50 dBA, while another 33% had unoccupied levels in excess of 50 dBA. The one outlier, *Nagarote,* missed the goal by 28 dB, but the results in this case are explained by the constant presence of loud music from the Evangelical church which was played all day, both when school was in session and out of session. No city or town in Nicaragua seems to have any municipal regulation of acceptable noise levels or acceptable times of transmission for amplified church music, ambulant publicity[3], or use of bus/truck horns. Machinery noise from factories or small business workshops is also unregulated. These forms of acoustic stimuli provide external noise to school classrooms in Nicaragua, and their impact upon the learning capacity of Nicaraguan children with hearing loss is of concern.

Occupied Noise Levels

None of the schools studied were able to meet the recommended occupied noise level of 50 dBA or less. The occupied levels exceeded the recommended levels by 6.5 to 25 dB. It is disturbing to note that the occupied levels for *Nagarote* do not occupy the extreme end of the range, as would be expected as *Nagarote* was at the extreme end of the scale for unoccupied levels. This school, which had constant external loud music, was exceeded in occupied levels by eight schools. A significant portion of occupied noise levels may have been provided by the children themselves. Children's spontaneous speech, moving of chairs, tapping of feet, and dropping of books appeared to be major sources of occupied noise levels.

As previously noted, the use of amplification by children with hearing impairments in Nicaragua is rare. One result of this practice is that children with severe-to-profound hearing losses have no auditory feedback about their own voices or about any noise that they cause in a classroom. Many of the children, however, are aware that voicing gains people's attention, and thus, in many classrooms, there is a significant amount of internal noise that is attributable to children screaming to gain the teacher's attention, protesting vociferously the transgressions of their neighbors, and scraping metal and wooden chairs across concrete floor tiles, actions that produce transient increases in noise levels to 80-100 dBA. If more children with hearing impairments wore functioning amplification consistently, it is possible that they would monitor their voice levels more and reduce the amount of chair scraping. Discipline also modifies the amount of internal noise in a classroom. In general, the children in the classrooms observed were quite noisy (not necessarily verbalizing), and teachers made little effort to reduce the level of spontaneous vocalization.

Reverberation

None of the classrooms met the reverberation goal of an RT_{avg} of 0.5 s, which is the goal for classrooms for normally-hearing children, and much less that of 0.3 s, which is the recommended goal for classrooms for children with hearing impairments. The lowest RT_{avg} were 0.7 s in *Chinandega* and *El Viejo,* with val-

[3]This is a common means used to broadcast paid announcements and advertisements throughout a community on short notice. A powerful speaker is mounted on the bed of a pick-up truck, and the truck cruises slowly up and down the streets as the message (which can be either pre-recorded on audiotape or spoken spontaneously into a microphone) is amplified to a level estimated to be hearable within the houses along the route. Death notices with announcements about funeral arrangements are common material for ambulant publicity, but notifications about electricity or water repairs, political announcements, and advertisements for various products are also typically heard.

ues under 1.0 s for *Estelí*, and *Nagarote*. At the other end of the range, RT_{avg} was 2.3 s in *Diriamba* and 1.7 s in *Matagalpa*. In addition to low RT_{avg}, it is also recommended that the RTs measured across frequencies be consistent (Nabelek et al., 1989). When a criterion of no more than 0.1 s difference between adjacent frequencies was applied, none of the classrooms met the criterion of consistency.

S/N Ratio

The S/N ratio was measured within the occupied classroom, and three (16%) classrooms met the levels recommended for listeners with hearing impairments (+10 S/N ratio). Seven other classrooms (39%) had S/N ratios between 0 and +9.9 dB, levels considered acceptable for normally-hearing listeners. Unfortunately, eight (44%) had levels with negative S/N ratios. Even normally-hearing children experience speech degradation under such circumstances. Teachers were able to improve the S/N levels by forcing their voices, but this practice cannot be recommended on a long-term basis because it leads to excessive fatigue for the teacher and probable vocal abuse (Child & Johnson, 1991).

SUMMARY AND DISCUSSION

When classroom construction was considered, all of the special education schools examined were found to have nearly no absorptive materials and be mainly made of hard, reflective surfaces. Many schools are located close to sources of external noise, such as main street arterials, bus stops, churches, markets, and restaurants. Only two schools met the goal of 40 dBA or less for unoccupied classrooms, and none met the occupied classroom goal (less than 50 dBA). All average reverberation times exceeded the goal of 0.3 s for children with hearing impairments, and in fact, none were able to meet the more generous level of 0.5 s recommended for normally-hearing children. Reverberation times were not consistent across frequencies. Only 16% of the classrooms had acceptable S/N levels for children with hearing impairments, and 50% could not meet the recommended levels for normally-hearing children.

Some manner of increasing absorption within these classrooms is needed. Use of carpeting and acoustic tile are not realistic given the climate and economic situation of the country. It is possible that some form of braided sisal, now used in floormats woven mainly for the tourist market, could be manufactured in a form that could be hung on the walls to increase sound absorption. Gluing felt to the metal feet of chairs and desks or placing slit tennis balls over the metal feet would decrease the transient noises caused by dragging chairs and desks across the tile floors. Increasing the use of shrubbery to act as acoustic barriers should be investigated. It is clear that the present acoustic conditions in Nicaraguan classrooms for the hearing impaired are not ideal, nor even adequate. Creative and attainable solutions are needed to improve these conditions.

ACKNOWLEDGEMENTS

The first author was supported during this study by a doctoral dissertation fellowship from the Fulbright Foundation. A fellowship from the National Security Exchange Program provided the acoustic equipment used in this study. Travel and incidental expenses of the study were covered by a portion of a research scholarship from the Pan-American Roundtables of Texas.

The authors would like to thank Desirée Román, director of the Division of Special Education of the Ministry of Education in Managua, Nicaragua for her support throughout this project. We would also like to thank the principals of all of the special education schools visited, and the teachers of the hearing impaired who participated in the measurements, for their cooperation with this study.

Partial results of this study were presented at the national convention of the American Speech-Language and Hearing Association held in Boston, Massachusetts November 20-23, 1997.

REFERENCES

American Speech-Language-Hearing Association. (1995). Position statement and guidelines for acoustics in educational settings. *Asha, 37*(Suppl. 14), 15-19.

Arguello Carazo, G. (1996a). *Normas para la planta física educativa.* Managua, Nicaragua: Proyecto de Fortalecimiento Institutional al MED, Convenio BID-FISE #729/OC-N1.

Arguello Carazo, G. (1996b). *Programa arquitectónico de necesidades proyecto ambientes educativos tipo.* Managua, Nicaragua: Proyecto de Fortalecimiento Institutional al MED, Convenio BID-FISE #729/OC-N1.

Berg, F.S. (1993). *Acoustics and sound systems in schools.* San Diego, CA: Singular Publishing Group, Inc.

Berg, F.S., Blair, J.C., & Benson, P.V. (1996). Classroom acoustics: The problem, impact, and solution. *Language, Speech and Hearing Services in the Schools, 27,* 16-20.

Child, D., & Johnson, T. (1991). Preventable and nonpreventable causes of voice disorders. *Seminars in Speech and Language, 1,* 1-13.

Convenio MED-CONESCAL. (October, 1980). *Criterios normativos para el diseño y evaluación de edificios de educación especial.* Managua, Nicaragua.

Crandell, C.C., & Smaldino, J.J. (1994). An update of classroom acoustics for children with hearing impairment. *Volta Review, 96,* 291-306.

Crandell, C.C., Smaldino, J.J., & Flexer, C. (1995). *Sound-field FM amplification: Theory and practical applications.* San Diego, CA: Singular Publishing.

Finitzo-Hieber, T. (1988). Classroom acoustics. In R. Roeser (Ed.), *Auditory disorders in school children* (2nd ed., pp. 221-233). New York: Thieme-Stratton Publishers.

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

Ministerio de Educación, Dirección de Educación Especial. (1997a). *Escuelas de educación especial con aulas de audición.* Managua, Nicaragua: Author.

Ministerio de Educación, Dirección de Educación Especial. (1997b). *Matricula 1997: Educación especial.* Managua, Nicaragua: Author.

Nabelek, A.K., Letowski, T.R., & Tucker, F.M. (1989). Reverberant overlap- and self-masking in consonant identification. *Journal of the Acoustical Society of America, 86,* 1259-1265.

Nabelek, A.K., & Mason, D. (1981). Effect of noise and reverberation on binaural and monaural word identification by subjects with various audiograms. *Journal of Speech and Hearing Research, 24,* 375-383.

Nabelek, A.K., & Pickett, J.M. (1974). Reception of consonants in a classroom as affected by monaural and binaural listening, noise, reverberation, and hearing aids. *Journal of the Acoustic Society of America, 56,* 628-639.

Pacheco Pilon, F. de M. (1996a). *Aspectos normativos technico-pedagogicos del local escolar.* Managua, Nicaragua: Proyecto de Fortalecimiento Institutional al MED, Convenio BID-FISE #729/OC-NI.

Pacheco Pilon, F. de M. (1996b). *Aspectos pedagogicos de los parametros que determinan el local escolar.* Managua, Nicaragua: Proyecto de Fortalecimiento Institutional al MED, Convenio BID-FISE #729/OC-NI.

Peutz, V.M.A. (1971). Articulation loss of consonants as a criterion for speech transmission in a room. *Journal of the Audio Engineering Society, 19,* 915-919.

Pfeifer, F. (1993). *Lärmstörungen: Gutachten und lärm-lexikon* (6th ed.). Düsseldorf, Germany: Verlag Deutsche Wohnwirtshaft GmbH.

Silliman, E.R., & Wilkinson, L.C. (1991). *Communicating for learning: Classroom observation and collaboration.* Gaithersburg, MD: Aspen Publishers.

Webster, J.C., & Snell, K.B. (1983). Noise levels and the speech intelligibility of teachers in classrooms. *Journal of the Academy of Rehabilitative Audiology, 16,* 234-255.