Noise Levels in Urban Nursing Homes for the Elderly: Implications for Communication

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Elderly people with normal hearing have increased difficulties understanding speech in noisy environments. Many elders are hearing impaired and have even greater difficulties understanding speech in noise. Poor speech understanding due to high levels of background noise may result in a decline in the quality of life for elderly persons. The present research involved a survey of 20 nursing homes that provided services to elders who were in poor health and required constant care, in highly urbanized Hong Kong. The nursing homes were surveyed for background noise levels in commonly frequented locations and for noise reduction measures already in use. The survey results suggest that more may need to be done to improve the acoustic environment in many urban nursing homes, as existing background noise levels may be too high to support good speech communication.

By definition, noise is any type of undesired sound (Berglund & Lindvall, 1995). Noise can have an adverse effect on mental and physical health (Tempest, 1985), reduce our efficiency, and affect our quality of life. Successful conversation and understanding of speech are prerequisites for an acceptable quality of life (Lazarus, 1987). However, noise interferes with communication because masking occurs when noise overrides parts of a speech signal. Speech may become inaudible or unintelligible to the listener. Speech-to-noise ratio (SNR) is one of the

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most widely used indices for quantifying speech interference due to noise (Berglund & Lindvall, 1995). Gat and Keith (1978) found that young adults with normal hearing could achieve average correct single word recognition scores of 88%, 86%, and 74% with SNRs at +12 dB, +6 dB, and 0 dB respectively. Conversations generally contain many contextual cues, allowing effective communication for adult listeners with normal hearing even when the intensities of noise and speech are equal (SNR = 0).

Some populations require a much more favorable SNR to achieve optimal spoken communication. Reduction in the speech perception abilities of elderly people with normal hearing in noisy environments is more pronounced than for younger adults in the same environments (Tun & Wingfield, 1999). One of the underlying explanations for these difficulties lies in the deterioration of cognitive processing abilities of elders (Crandell, Henoch, & Dunkerson, 1991). Elderly persons require an SNR that is 10 dB to 20 dB higher compared to younger adults to achieve the same speech perception scores (Nabelek & Nabelek, 1994). As a result, elders need an SNR of +10 dB to +20 dB for optimal speech recognition in daily life (Berglund & Lindvall, 1995; Nabelek & Nabelek, 1994).

The noise levels of homes for the elderly play an important role in speech communication among residents and between residents and staff. Beranek, Blazier, and Figwer (1971) developed room noise criteria ratings that are still widely used. The recommended noise level of conversation areas in residences of the type discussed in this report should not be higher than 47 dBA. Under such conditions, elders can maintain an adequate SNR (10 - 20 dB) for a speech input level at about 60 - 66 dBA during a typical conversation at 1 m distance (Berglund & Lindvall, 1995). If the noise is higher than the recommended level, elderly people may face two problems. First, individuals can adjust their voice volume to overcome the masking effect of noise by adducting their vocal folds strongly. Voice disorders can result in the long term for those who spend considerable time talking above high levels of ambient noise (Colton & Casper, 1996, p. 87), such as full-time nursing home staff. Second, if speakers cannot or do not adjust their vocal intensity in areas of increased noise, the SNR will be less than optimum and communication breakdown may result. In this situation elderly persons may experience feelings of isolation and their quality of life may decline (Crandell et al., 1991).

Lankford and Hopkins (2000) conducted a study of ambient noise levels in 10 nursing homes in northern Illinois. They measured 33 rooms including common areas, residential rooms, and staff/conference rooms. There was no significant difference in noise level among these three categories. The average overall noise level of these rooms was 42.3 dBA, within the recommended level of Beranek et al. (1971). However, the population density of major world cities is much higher than that in the Lankford and Hopkins study. Hong Kong, with 6.8 million persons, is one of the 25 most populous world cities. It has a high population density – 6,300 people per square kilometer (Government of Hong Kong, 2002a) – and there are many people affected by excessive noise, as evidenced by the 12,487 noise pollution complaints registered with the Environmental Protection Department in 2001 (Government of Hong Kong, 2002a).

In Hong Kong, the elderly population has grown rapidly. According to official estimates, nearly 2 million people, about one fifth of the total projected population in Hong Kong, will be aged 60 or above by 2031 (Census & Statistics Department, 2002). There are at present nearly 800,000 people who are defined as elderly (aged 65 years or above) in Hong Kong (Census & Statistics Department, 2003). Although many elders in Hong Kong live in their own homes, nursing homes provide an additional 72,915 places for elderly persons (Government of Hong Kong, 2002b); therefore, it is important to measure noise in these settings. The elderly population is a high-risk group for hearing impairment (Yueh, Shapiro, MacLean, & Shekelle, 2003), but there has been little research on the impact of noise on communication in nursing homes despite the steps that can be taken to minimize the adverse effects of noise (Harris & Reitz, 1985).

The present study was designed to assess overall noise levels in homes for the elderly, and to determine if noise exceeded the recommended levels proposed by Beranek et al. (1971). The study also quantified the SNRs for elderly residents and the staff of nursing homes and compared them to desired levels. In addition, ambient noise levels in the quietest locations were compared to American National Standards Institute (ANSI; S3.1-1999) maximum permissible ambient noise levels (MPANL) for hearing assessment by pure tone audiometry. This was to determine if valid pure tone audiometry could be performed in the acoustic environments of the nursing homes. Nursing homes were, at the same time, surveyed to determine their existing acoustic modifications (such as double paned windows and acoustic ceiling tiles). The study focused on homes for the elderly where care-and-attention home services are provided. This type of nursing home is the most common in Hong Kong (Social Welfare Department, 2002) and provides a residential service to elderly people who are in poor health and need constant care. Other nursing homes in Hong Kong serve as day-care only centers.

METHOD

Nursing Homes

Twenty residential nursing homes for the elderly throughout Hong Kong were included in this study. Ten were located in the Hong Kong Island/Kowloon region. This locality developed rapidly in the 1950s to 1970s with little urban planning. The other nursing homes were located in the New Territories, a region consisting of rural areas and new towns with considerable urban planning. Half in each area were government subsidized homes and half were non-government subsidized homes. Homes were selected from the 573 existing Hong Kong institutions to provide a survey sample with a variety of geographic and economic settings within the region.

The administrators of these homes were contacted by letter or fax describing the purpose of the study, the procedure for measuring noise levels and speech levels, and the amount of time required for data collection. After the survey visit, each nursing home received a brief report concerning its acoustic environment and recommended improvements. The nursing homes covered a wide construction period, from 1957 to 1999, with an average building age of 21 years. All homes were constructed of concrete, with no observable differences in building style between government and non-government facilities.

Subjects

The number of elderly residents in each nursing home ranged from 38 to 250 persons ($M = 122$, $SD = 77.9$). The number of staff ranged from 8 to 120 persons ($M = 41$, $SD = 28.1$). In order to measure speech levels, 3 elderly residents aged 65 or above and 3 staff were randomly selected as subjects at each center. Subjects chosen were literate and free from any speech, language, or hearing disorder, as determined by an on-site speech/language assessment and hearing screening, and had no known cognitive deficits. Hearing screening was conducted using noise-excluding circumaural headphones. The "pass" criterion was 25 dB HL at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. Written consent was obtained from each subject prior to the measurements.

Procedures

Homes for the elderly were visited on weekdays (Monday to Saturday, except public holidays) from 9:30 to 11:30 a.m. or 2:00 to 4:00 p.m. Lunch hour was excluded due to the inconvenience measurements would cause residents and staff. Elderly residents were involved in routine leisure activities at the time of the survey. Television and/or radio were usually playing during the measures. The survey was conducted during winter in Hong Kong and air-conditioners were usually not in use. Some windows were open at each location. No special or extraordinary events (e.g., open house or health fair) were occurring. Each survey visit lasted for 30 to 60 min.

Survey of Acoustic Facilities

In each home for the elderly, the administrator was interviewed about the presence of acoustical treatment. Treatment included the use of carpeting, double paned windows, ceiling tiles, acoustically modified walls, and acoustically soft furnishings. Such measures were considered present when they covered at least 50% of a total room surface area. The presence and the frequency of use of amplification systems, frequency modulation (FM) systems, and public address (PA) systems were also determined. Since a well functioning air-conditioner can allow windows to be closed and can therefore reduce external noise, at least in warmer months, the extent of air-conditioning use was also considered.

Noise Levels

Noise level measurements took place in two areas. The first was the common area, defined as the area where residents congregated for leisure or group activities (Lankford & Hopkins, 2000). Conversation between people very frequently took place at this area. The second area selected was the quietest known room, as reported by the administrator of each nursing home. Such an area could be a conference room, a nursing station, or an unoccupied bedroom. The size of the area, the number of people, and the noise from adjacent areas were not controlled in order to study real world conditions.

The noise levels were obtained with a Brüel & Kjær 2235 sound level meter with an attached Brüel & Kjær 1625 1/1 - 1/3 octave band filter set. The sound level meter was calibrated before the study commenced and regularly checked during the study. The microphone of the meter was placed at the center of the selected areas at a 1 m height on a tripod. A 1 m height was chosen because it was approximately the ear level of seated elderly residents. The researcher was located at a 0.5 m distance from the microphone, to ensure minimal effect on data recording (Markides, 1986). The noise measures were made using a dB A-weighted scale, slow response setting. Sound pressure levels for octave bands at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz were also measured without applying the A-weighted scale (i.e., in dB SPL). Survey noise measurements were taken three times within 10 min (at commencement, at the fifth minute, and at the tenth minute). The noise level reported for each area was the average of these three measures.

Speech Levels and SNR

Subjects recruited from the homes for the elderly were requested to read aloud in Cantonese a simple Chinese passage comprised of 142 characters, at a level they would use when talking to friends at about 1 m distance. Each subject sat at the center of the common area while everyday activities took place. Speech intensity levels in dBA were obtained using the same sound level meter. The microphone was placed at 1 m in front of each subject's mouth on a tripod, simulating a typical distance between two people during normal conversation. During the reading, the speech level of each subject was sampled three times, at the midpoint of the first line, fourth line, and seventh line of the passage. The data were then averaged to give a single value representing the speech level of the subject. The final average speech level of staff and elderly residents at each nursing home was the average of 3 staff and 3 elderly residents respectively. The SNRs produced by the staff and elderly residents were calculated by subtracting the averaged common area noise level of their nursing home from their respective final average speech levels. For data analysis purposes, parametric methods were generally used. Non-parametric tests were used as an alternative in cases where the homogeneity of variance rule for parametric tests was violated. Unless otherwise stated, all statistical procedures used in this study were two-tailed tests.

Reliability Measures

To determine the degree of reliability, 25% of the homes for the elderly were randomly selected for revisit after 1 to 2 months. The procedure of the revisit survey was the same as for the first one and the data collected at the two visits were compared. The elders and staff who participated in the initial procedures took part in the retest measures.

RESULTS

Noise Levels, Speech Levels, and SNRs in Common Areas

The average overall noise level in the common areas of the nursing homes was 64 dBA ($SD = 6.22$). Table 1 summarizes the common area data, both for overall noise levels and for noise in the four octave bands from 500 Hz to 4000 Hz. Only one nursing home met the recommended 47 dBA average noise level (Beranek et al., 1971).

The noise levels of government subsidized homes for the elderly ($M = 66.65$, $SD = 2.83$) were significantly higher than for non-government subsidized ones ($M = 61.16$, $SD = 7.43$), $U(N_A = N_B = 10) = 24.00$, $p < .05$. However, there was statistically no difference between noise levels in the different regions (Hong Kong Island/Kowloon and the New Territories), $t(18) = 0.82$, $p = .42$.

As noted in Table 1, the average noise levels at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz in dB SPL were 61.96 ($SD = 6.61$), 58.65 ($SD = 7.03$), 55.57 ($SD = 6.66$), and 49.91 ($SD = 6.72$) respectively. A one-way ANOVA revealed a significant effect of frequency, $F(3, 57) = 86.10$; p (one-tailed) $< .01$. Post-hoc analysis using the Tukey HSD test showed that noise at 500 Hz was significantly higher than at other frequencies, $p < .01$.

The speech levels of staff and elderly residents in nursing homes are shown in Figure 1 and Table 2. The averaged speech level of staff was 71.5 dBA ($SD = 5.32$). It was 2 dB higher than for elderly people ($M = 69.6$ dBA; $SD = 5.25$) but the difference was not statistically significant, $t(38) = 1.16$, $p = .25$. Eighty-five percent of the averaged staff values and 80% of the values for the elderly residents exceeded 66 dBA, a typical conversational speech level (Berglund & Lindvall, 1995). The difference in averaged staff speech levels between government subsidized homes ($M = 74.37$; $SD = 1.80$) and non-government subsidized ones ($M = 68.69$; $SD = 6.22$) was statistically significant, $U(N_A = N_B = 10) = 13.00$, $p < .01$, but not for elderly residents, $U(N_A = N_B = 10) = 29.00$, $p = .11$. Average

Table 1

Noise Level at the Common Areas

Home	Year	Location[a]	Administration[b]	Overall[c]	500 Hz[d]	1000 Hz[d]	2000 Hz[d]	4000 Hz[d]
A	1978	R	G	71.20	68.73	65.50	56.90	52.03
B	1980	R	G	64.37	63.93	56.93	57.97	49.60
C	1981	U	G	68.57	67.27	59.83	58.83	55.20
D	1983	R	G	65.53	62.20	62.07	57.23	52.17
E	1983	U	G	63.53	62.37	61.30	57.00	47.97
F	1991	U	G	69.40	66.43	64.27	61.00	58.80
G	1991	R	G	68.87	68.27	64.83	62.30	52.73
H	1994	U	G	63.57	61.53	54.60	51.93	51.53
I	1997	R	G	69.43	68.77	64.10	58.10	52.97
J	1999	U	G	65.00	62.40	65.67	64.67	54.03
K	1957	U	N	55.73	50.63	48.50	46.40	38.80
L	1960	U	N	61.30	61.27	54.67	53.67	47.10
M	1960	R	N	72.27	66.03	68.43	67.43	58.70
N	1962	U	N	55.90	56.10	49.30	45.30	38.93
O	1970	R	N	65.23	58.23	55.77	54.77	55.60
P	1970	R	N	45.90	41.90	39.67	38.67	31.70
Q	1975	R	N	66.83	58.53	58.20	57.20	50.40
R	1990	U	N	59.40	62.20	55.73	51.33	49.00
S	1998	R	N	62.47	65.93	63.50	56.47	48.63
T	1999	U	N	66.63	66.53	60.20	54.27	52.33
M	1980			64.06	61.96	58.65	55.57	49.91
SD				6.22	6.61	7.03	6.66	6.72

[a] U = "urban"/Hong Kong Island or Kowloon; R = "rural"/New Territories. [b] G = government subsidized; N = non-government subsidized. [c] = dBA. [d] = dB SPL.

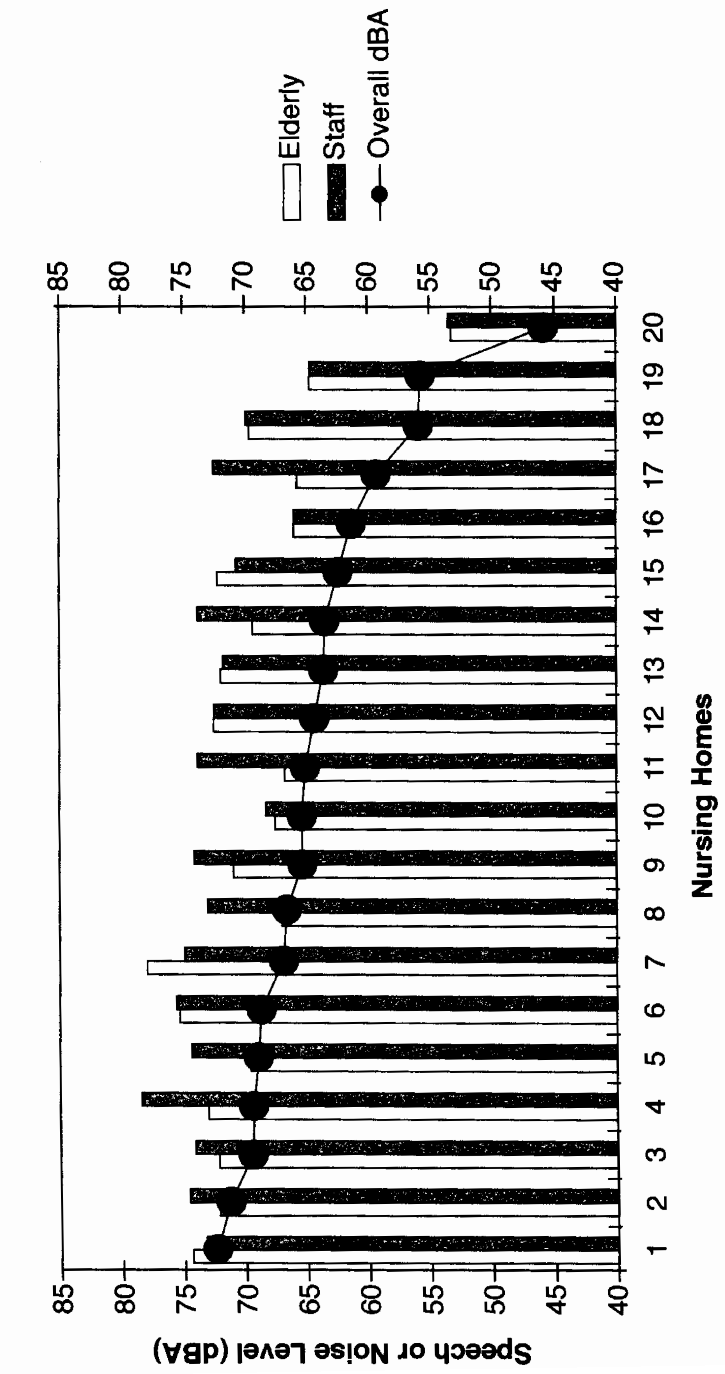

Figure 1. Speech levels of staff and elderly residents, with nursing homes re-ordered according to overall nursing home noise level.

Table 2

Speech Levels and Speech-to-Noise Ratio (SNR)

Home	Year	Location[a]	Administration[b]	Elderly speech[c]	Staff speech[c]	Elderly SNR[d]	Staff SNR[d]
A	1978	R	G	72.29	74.71	1.09	3.51
B	1980	R	G	72.63	72.58	8.26	8.21
C	1981	U	G	75.34	75.76	6.77	7.19
D	1983	R	G	70.98	74.12	5.45	8.59
E	1983	U	G	69.39	73.87	5.86	10.34
F	1991	U	G	72.10	74.13	2.14	4.73
G	1991	R	G	69.52	74.42	0.65	5.55
H	1994	U	G	72.13	71.82	8.56	8.25
I	1997	R	G	73.19	78.46	3.76	9.03
J	1999	U	G	66.78	73.84	1.78	8.84
K	1957	U	N	64.54	64.80	8.81	9.07
L	1960	U	N	65.94	65.99	4.64	4.69
M	1960	R	N	74.39	73.33	2.12	1.06
N	1962	U	N	69.71	69.80	13.81	13.90
O	1970	R	N	67.46	68.36	2.23	3.13
P	1970	R	N	53.32	53.63	7.42	7.73
Q	1975	R	N	78.00	74.98	11.17	8.15
R	1990	U	N	64.79	72.42	5.39	13.02
S	1998	R	N	72.12	70.58	9.65	8.11
T	1999	U	N	67.08	73.01	0.45	6.38
M	1980			69.59	71.53	5.50	7.47
SD				5.25	5.32	3.77	3.13

[a] U = "urban"/Hong Kong Island or Kowloon; R = "rural"/New Territories. [b] G = government subsidized; N = non-government subsidized. [c] = dBA. [d] = dB SPL.

speech levels across regions were not statistically different, $t(18) = 0.67$, $p = .51$ (elderly residents); $t(18) = 0.01$, $p = .99$ (staff). There was a clear relationship between the vocal intensity of staff and residents and the noise levels of their nursing homes, with a Pearson correlation of $r = .86$ ($p < .01$) for staff and $r = .80$ ($p < .01$) for residents.

As shown in Table 2, the average SNR of staff and elderly residents was 7.5 dB ($SD = 3.13$) and 5.5 dB ($SD = 3.77$) respectively. The difference between elderly residents and staff was not statistically significant, $t(38) = 1.80$, $p = .08$. Only one home for the elderly had an SNR at 10 dB or above for both elderly residents and staff, which is a recommended minimum value for optimal communication. The differences between government and non-government subsidized nursing homes was not statistically significant for either elderly residents, $t(18) = 1.28$, $p = .21$ or staff, $t(18) = 0.07$, $p = .95$. There was also no difference between homes in different regions, $t(18) = 0.37$, $p = .71$ (elderly residents) and $t(18) = 1.75$, $p = .10$ (staff).

Noise Levels in the Quietest Locations

The noise levels in the quietest nursing home locations are summarized in Table 3. The average overall noise level was 49.4 dBA ($SD = 9.18$). The difference between government and non-government subsidized nursing homes was not statistically significant, $t(18) = 0.85$, $p = .40$, nor was the difference between regions, $t(18) = 1.81$, $p = .09$.

Figure 2 shows the average noise levels across each octave band (500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) measured at the quietest possible locations. Additionally, Figure 2 shows ANSI S3.1-1999 MPANL standards for hearing assessment by pure tone audiometry. The average noise levels at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz were 46.8 ($SD = 8.88$), 43.8 ($SD = 9.81$), 39.9 ($SD = 9.58$), and 33.9 dB SPL ($SD = 8.80$), respectively. These results indicate that, in such an environment, supra-aural headphone assessment should be considered at 4000 Hz and that non-occluded bone conduction testing should not be attempted at any frequency from 500 to 4000 Hz. However, the mean ambient noise figures suggest that valid assessment via insert earphones for a wide test frequency range is feasible in a number of the quietest nursing home locations.

Test-Retest Reliability

Five homes for the elderly were revisited after 1 to 2 months. The overall noise level measurements (both measurements in the common area and the quietest location) between the two visits had high intra-class correlation ($r_i = .98$) with a mean absolute difference of 1.24 dB. Octave band measurements (both measurements in the common area and the quietest location), between visits were also highly correlated, $r_i = .99$, with a mean absolute difference of 1.21 dB. In these

Table 3

Noise Level at the Quietest Possible Areas

Home	Year	Location[a]	Administration[b]	Overall[c]	500 Hz[d]	1000 Hz[d]	2000 Hz[d]	4000 Hz[d]
A	1978	R	G	55.93	53.80	47.83	45.40	33.50
B	1980	R	G	47.10	43.53	38.87	34.37	26.67
C	1981	U	G	52.13	49.90	48.53	44.30	38.17
D	1983	R	G	41.60	35.77	31.43	28.37	25.63
E	1983	U	G	47.63	44.23	42.87	39.60	33.03
F	1991	U	G	52.10	50.67	48.37	43.63	37.13
G	1991	R	G	48.83	48.90	42.00	40.97	34.37
H	1994	U	G	44.80	45.10	37.77	37.30	30.77
I	1997	R	G	45.47	46.97	38.10	35.07	29.27
J	1999	U	G	41.17	35.83	37.43	35.23	26.17
K	1957	U	N	53.97	48.13	49.43	45.17	39.40
L	1960	U	N	67.10	59.57	61.57	57.30	48.67
M	1960	R	N	50.80	49.47	49.83	43.30	35.83
N	1962	U	N	54.70	53.80	48.83	45.57	40.67
O	1970	R	N	55.83	49.50	49.20	48.60	43.97
P	1970	R	N	25.30	23.63	14.73	11.97	11.27
Q	1975	R	N	34.80	34.87	38.20	29.10	24.60
R	1990	U	N	52.80	49.87	47.60	45.23	40.63
S	1998	R	N	53.53	51.70	47.97	38.70	30.67
T	1999	U	N	61.40	61.53	55.27	49.23	47.17
M	1980			49.35	46.84	43.79	39.92	33.88
SD				9.18	8.88	9.81	9.58	8.80

[a] U = "urban"/Hong Kong Island or Kowloon; R = "rural"/New Territories. [b] G = government subsidized; N = non-government subsidized. [c] = dBA. [d] = dB SPL.

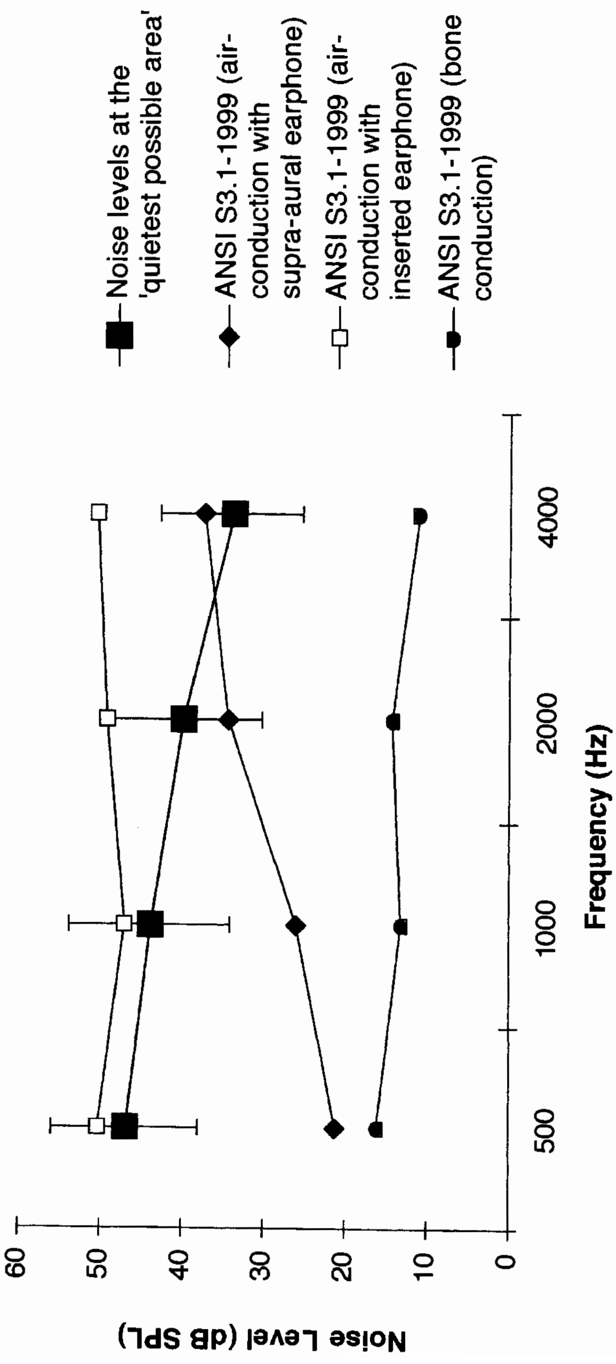

Figure 2. Noise level averages and standard deviations across octave bands in quiet locations, compared with American National Standards Institute (ANSI) S3.1-1999 maximum permissible ambient noise level (MPANL) standards.

five homes for the elderly, 25 subjects, including elderly residents and staff, participated in a retest of the speech level measures. The average value of each individual speaker was calculated. These values also showed a high test-retest correlation, $r_i = .99$, with a mean absolute difference of 1.91 dB.

Survey of Acoustic Facilities

Only two nursing homes for the elderly (10%) used floor carpeting. None used double paned windows, ceiling tiles, acoustically modified walls, or acoustically modified furniture. Although 17 centers (85%) had installed air-conditioners, only one nursing home used them continuously throughout the year. Others used them for the summer months only, opening windows at other times. Eleven homes for the elderly (55%) had installed PA systems for amplification and used them on a daily basis. No nursing home had installed FM systems or other devices alternative to PA systems to amplify speech signals.

DISCUSSION

The results indicate that the noise levels in nursing homes for the elderly in highly urbanized areas such as Hong Kong may have adverse effects on residents' communicative abilities and be poor locations for pure tone audiometric testing. The average overall noise level for common areas was 64 dBA. This was 17 dB higher than the recommended level for conversational and leisure activity areas (Beranek et al., 1971). Moreover, this was an average noise level, with some homes having much higher levels of up to 72 dBA. Only 1 of the 20 nursing homes surveyed met the Beranek et al. (1971) recommendation. The average noise level in the quietest locations in the nursing homes also exceeded this level, with only 35% of "quiet" locations meeting the recommendation. Unsurprisingly, government subsidized nursing homes were noisier than non-government homes. Non-subsidized homes are usually located in private buildings, whereas government subsidized centers are usually located on the ground floor of large public housing estates. Noise generated from passing estate residents, estate shops, or nearby traffic easily penetrates into these buildings. It was also not surprising to find no significant differences in noise level among nursing homes in the three regions of Hong Kong. The rapid urbanization of the New Territories in the past few decades has blurred any *urban* and *non-urban* categorizations. Such a highly urbanized environment shows very different results compared to those obtained in less urbanized regions. Using similar procedures to the present study, Lankford and Hopkins (2000) found an ambient noise mean of only 42.3 dBA for nursing home rooms in urban and rural areas of northern Illinois, with a range in ambient room noise from 30 to 57 dBA.

In addition, the study also revealed that the intensity of low frequency noise (500 Hz) was consistently greater than for high frequencies, as was noted in the Lankford and Hopkins (2000) report. Such noise typically comes from external sources such as traffic and construction activities. Low frequency noise has more adverse effects than high frequency noise as it can also produce masking effects in mid and high frequencies, which contain the majority of speech cues (Crandell & Smaldino, 1994).

To describe the degree of speech interference in nursing homes, the speech levels of elderly people and center staff also have to be taken into account. At 1 m distance, the speech of a relaxed conversation is typically 50 - 55 dBA. Speech levels can automatically rise to 60 - 66 dBA in noisy environments (Berglund & Lindvall, 1995). However, based on the average speech levels collected in this study, elderly residents and staff typically raised their voices to 70 dBA and 72 dBA respectively at 1 m distance. This suggested residents were using a loud voice in an attempt to maintain a positive SNR. Among 20 homes for the elderly, the average SNR of elderly residents and staff was +5.50 and +7.47 dB respectively. However, such an SNR level is just adequate for adults with no hearing impairment (Crandell & Smaldino, 1994) and is well below the recommended target range of +10 to +20 dB for elderly persons. In summary, the SNRs noted for staff and elderly residents indicate that consistently successful and reliable verbal communication among individuals in the surveyed homes for the elderly was unlikely, despite a consistent trend for both residents and staff to increase vocal intensity levels with increased ambient noise. In order to improve the SNR, attempts should be made to increase speech levels further without causing discomfort, or noise levels should be reduced. For the past few decades, a number of acoustic treatments have been proven to reduce noise effectively (Technical Committee on Architectural Acoustics of the Acoustical Society of America, 2000). It was a disappointing finding in this study that nursing homes for the elderly in Hong Kong seldom use such treatments.

Urban noise often comes from the external environment, and building structures are poor in attenuating low frequency noise of external origin. Successful external noise reduction is important for communication. Introducing sound barrier systems such as closed double paned windows can reduce noise transmission by 40 dB (Harris, 1991). However, in order to achieve noise reduction, windows need to be closed all day, with a well-functioning ventilation system. The placement of shrubs or trees on earthen banks around buildings can also reduce external environmental noise through absorption and interference. Building maintenance is also important. All walls should be free from cracks and openings to prevent penetration of external noise. External noise reduction can also be achieved by careful planning, such as locating the main communication areas away from external noise sources; placing non-communication rooms, such as storerooms, closest to external noise sites; and ensuring doors and windows facing noise sites are well sealed and closed most of the time (Crandell & Smaldino, 1994). Besides external noise reduction, internal noise can be effectively reduced by sound absorption materials (Harris, 1991), particularly acoustic paneling on the walls and ceiling.

During the present study it was observed that many nursing homes provided television or radio in the common area from morning to evening at a loud volume while often few elderly people watched or listened. Although it is reasonable to provide elders with television and radio facilities in the common area, the volume should be carefully adjusted so that it does not impair communication in general. Alternatively, the provision of "quiet rooms" designated for conversation only may be considered.

Increasing speech levels is another means to enhancing SNR. Apart from raising the intensity of their own voice, residents and staff can use speech amplification systems. Some nursing home staff frequently used portable PA systems, which can amplify speech signals up to a 90 - 100 dB SPL level, to communicate in small or large group situations. FM radio amplification systems are also recommended for residents and staff in nursing homes for the elderly, especially in homes that have a large proportion of hearing impaired elderly residents. These systems can link to a personal hearing aid or to loudspeaker systems.

Elderly people with hearing impairment living in nursing homes are especially at risk of communication breakdown (Maurer, 1979) and they require additional consideration. It is often desirable to obtain audiometric thresholds for such residents of nursing homes. By comparing the noise levels of the quietest possible nursing home locations to the ANSI S3.1-1999 MPANL criteria, it can be seen that noise levels were too high for conventional hearing assessment. No nursing homes met standards for threshold assessment via air-conduction audiometry with conventional supra-aural earphone or bone conduction audiometry for a frequency range from 500 Hz to 4000 Hz. Only 45% of locations were suitable for hearing assessment throughout the same frequency range with air conduction audiometry via insert earphone. In contrast, Lankford and Hopkins (2000) found that 91% of nursing homes in their northern Illinois study met standards for assessment via air-conduction audiometry with insert earphones for a frequency range from 500 Hz to 4000 Hz. The noise level of a potential hearing assessment location should therefore be carefully evaluated and compared to these standard criteria before performing hearing checks. Additionally, quiet locations in nursing homes are chosen as areas for individual speech therapy, counseling, or other health care activities. Results of the present study suggest that attention needs to be given to these areas to ensure that the acoustic environment allows clear communication to take place.

Noise is not the only factor that impairs speech perception. Room reverberation also has an impact on speech perception (Harris & Reitz, 1985) by reflecting speech sound from walls, ceiling, and other barriers. The reflected, delayed sounds can mask the original signal. This study did not measure the reverberation time of the sampled nursing homes and this factor should be considered in future research.

CONCLUSIONS

The communicative environment of nursing homes for the elderly in urbanized Hong Kong was revealed to be generally unacceptable in this study. Both staff and elderly residents often used raised voices but did not attain the recommended SNR. Communication breakdown could be common in such environments and the quality of life for the elderly may be reduced. Although the communication environments did not meet recommended standards, homes for the elderly that were visited in this study seldom employed acoustic treatment to improve the SNR of staff and elderly residents. The results may be typical for nursing home environments in many of the world's larger, more densely populated cities. Nursing home administrators need to carefully consider noise management issues to ensure that the quality of life of elders is not compromised by a poor communication environment. Health care professionals, particularly those heavily dependent on clear communication (such as audiologists, speech therapists, and counselors) need to pay special attention to the acoustic environment of nursing homes when planning residential assessment or treatment programs.

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