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SPEECH LEVELS IN VARIOUS NOISE ENVIRONMENTS

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SPEECH LEVELS IN VARIOUS NOISE ENVIRONMENTS

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ABSTRACT

Research on speech level measurements was conducted under laboratory and non-laboratory conditions. The goal of this study was to determine average speech levels used by people when conversing in different levels of background noise.

The non-laboratory or real-life environments where speech was recorded were: high school classrooms, homes, hospitals, department stores, trains and commercial aircraft. Briefly, the results of speech measurements at schools confirmed that teachers in typical classroom situations speak at a consistently higher level (67-78 dB at one meter) than in face-to-face conversation. Further, their vocal effort increased at the rate of 1 dB/dB increase in background noise which ranged from 45 to 55 dB.

The speech levels recorded in face-to-face conversation were lower, averaging 55 dB at 1 meter for ambient levels less than 48 dB. But, as the background level increased above 48 dB to 70 dB, people correspondingly raised their voice levels up to 67 dB at the rate of 0.6 dB/dB as the ambient increased. It was also noted that for background levels less than 45 dB, speech levels measured at the listener's ear - disregarding distance between talkers - was also 55 dB.

The laboratory portion of the study was conducted in an anechoic chamber. The analysis of approximately 100 observers for four varied speech instructions ("Speak in a *normal, raised, loud,* and *shout* voice") showed an orderly progression in level, and

shift in spectral emphasis as voice levels increased. A comparison of male and female voice levels for the speech categories *normal* and *raised* yielded minimal differences, thus negating conclusions by other researchers that background levels should be lowered to accommodate female speech.

This report concludes with recommended background levels to achieve speech intelligibility for the various environments investigated in this study.

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ACKNOWLEDGEMENTS

The authors thank Suyeo Tomooka for his diligent assistance in data collection and analysis. Thanks also go to Brian Curtis for his assistance in recording speech and background levels and data analysis.

I. INTRODUCTION

Speech communication, although an essential aspect of daily life, is often degraded by the masking effects of background noise. EPA has identified various noise levels intended to guarantee adequate speech communication. These noise levels were identified on the basis of existing knowledge, rather than specific research programs. The current research was undertaken to provide a firmer basis for specifications of noise levels that insure adequate speech communication in a variety of real world settings.

To provide information for specifying the noise level in environments where speech communication may take place, one needs to know most crucially the distance over which people choose to communicate, and the speech levels at which people normally converse. Secondary factors may influence speech intelligibility as well, notably familiarity of the talker and listener with the language, the hearing acuity of the listener, visual cues, the amount of redundancy in the speech material, and reverberant characteristics of the acoustical environment. However these secondary factors remained fairly constant for a given speech measurement situation.

The distance between the talker and listener is important primarily when the conversation takes place in an outdoor environment, in which speech levels are typically reduced 6 dB for every doubling of distance of separation between the talker and listener. Indoors, particularly in home environments with relatively small rooms, the distance between the talker and listener is not as critical, since speech levels do not decrease in the same fashion as in the outdoor environment. This is particularly true for distances greater than 1 meter, since at these distances the listener is in the reverberant field and speech levels usually remain nearly constant with distance.

Thus, the principal factor that determines the adequacy of speech communication is the level produced by the talker. Most measurements of speech levels have been taken in very quiet environments (such as anechoic chambers), with a talker instructed to read from prepared text or word lists. Brown et al. (1976) have recently shown that even these data can be highly variable. Since it is important to determine speech intelligibility in environments other than laboratories, direct measurements of actual speech levels normally employed in environments are needed.

The study reported here provides measures of typical speech levels in homes, schools, hospitals, public places, and trains, and airplanes. To supplement this information and to make available detailed information on speech spectra, measurements were also made of speech levels in an anechoic chamber. Tabulations of one-third octave band statistical distributions of the speech levels for the anechoic measurements are provided in the data supplement of this report.

II. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Several conclusions may be drawn from the data collected and analyzed in this project.

1) Schools

In the classroom (lecturing) environment the teachers' speech levels increased at the rate of 1 dB/dB increase in background noise for ambient levels of 45 to 55 dB. The teachers' speech levels at 1 meter ranged from 67 to 78 dB.

2) Face-to-Face Communication

a) For background levels less than 45 dB, levels measured at the listener's ear averaged 55 dB.

b) For background levels less than 48 dB people maintained an average voice level of 55 dB when the effects of distance were normalized to 1 meter.

c) For background levels above 48, up to 70 dB, people began to raise their voice levels, up to an average of 67 dB, at the rate of 0.6 dB/dB increase in the ambient level. The speech levels were normalized to 1 meter.

d) Distances at which people communicate steadily decrease with increased background level. In ambient levels up to 45 dB, such as those found in the homes, communication distances averaged 1 meter. For higher background levels (above 70 dB) this communication distance decreased to an average 0.4 meters.

e) High sentence intelligibility of virtually 100% can be easily achieved when the speech to background ratio is at least 10 dB. According to the results of this study, this ratio or better can be maintained with a background level below 45 dB.

f) Sentence intelligibility of 94%, according to this study, is possible with a zero speech to background ratio in an ambient of 70 dB.

3) Anechoic Chamber

The results of the laboratory study indicated that vocal emphasis shifted from the low frequencies to the high frequencies as the speech categories went from *normal* to *shout*. This trend is evidenced by a 1.6 octave shift in the maximum one-third octave band from 500 Hz found in the *normal* voice spectrum, to 1600 Hz in the *shout* spectrum.

B. Recommendations

1) Schools

The Environmental Protection Agency in the "Levels Document" (1947) recommended an indoor level for classrooms not to exceed $L_{eq(24)}$ of 45 dB. This criterion was based on the consideration of providing an educational environment with a minimum of speech interference activities. The results from this study described in this report revealed that the average background level for occupied classrooms, with no talking during a test, was an L_{eq} of 45 dB. However, the far more typical classroom environment consisted of some student-teacher, or interstudent communication. The ambient level during the normal classroom activity was 50 dB. Therefore, it is recommended that for an occupied classroom, the background level could be 50 dB which would provide 99% sentence intelligibility.

2) Face-to-Face Communication

a) Homes

The 45 dB background level measured in this study for the indoor residential environment agrees with the recommended criterion in the EPA "Levels Document" (1974). The EPA recommended an indoor L_{dn} of 45 dB for speech communication. This would permit virtually 100% sentence intelligibility. The recommended outdoor L_{dn} level was set at 55 dB which again corresponded to the average ambient found in this study for both urban and suburban environments. This level would permit an average sentence intelligibility of 98% at 1 meter.

b) Hospitals

The hospital interior level set by the "Levels Document" (1974) was L_{dn} of 45 dB. This criterion was based on minimizing activity interference and annoyance. The EPA document, however, failed to stipulate whether this level was based on measurements taken in the patients' rooms, or the operating rooms, or the nurses' stations. The background measurements made for this study yielded a background of 45 dB for the patients' rooms, but 52 dB for noise measurements taken at the nurses' stations. But, even with the higher background levels of 52 dB and a resulting decrease in the speech to background ratio, the level was such as to allow 99% sentence intelligibility at 1 meter.

c) Department Stores

Background levels in public places, such as department stores, were higher than the indoor levels in homes or hospitals. However, people raised their voice levels to maintain an adequate speech to noise ratio for communication. For such commercial places as retail stores, restaurants and general office environments, a background of 55 dB (EPA 1974, Table D-10) is an average level recommended by architects and noise control engineers as an acceptable noise background. The sample taken in department stores for this study agrees with the 55 dB level and will provide a communication environment to enable an average 98% sentence intelligibility at 1 meter.

d) Transportation Vehicles

The noise exposure levels in the trains and airplanes afforded less than desirable sentence intelligibility (<95%). The EPA "Levels Document" (1974) recommended background levels no higher than L_{eq} = 70 dB over a 24 hour period in order to protect against hearing loss. The ambient levels measured in the current study averaged 77 dB, presenting a danger of potential hearing loss and most certainly impeding communication. It is therefore suggested that a background level of 70 dB be viewed as a goal for speech communication in both trains and airplanes. This level would permit sentence intelligibility of approximately 95% at about 0.5 meter.

3) Future Research

It is further recommended that the Articulation Index calculation procedure (ANSI, 1969) should be reviewed to incorporate the new speech spectra information obtained in the anechoic chamber laboratory study. Additional changes in the standard would be the inclusion of the new data on differences between peak and long term rms speech levels.

The data collected in the present study was from participants with normal hearing. The speech levels that other segments of the populous use for communication in various environments might bear some investigation. The elderly, or the hard of hearing at all ages use public transportation, and in order to facilitate proper usage of a transportation system such as a commuter train, it is vital they be able to communicate adequately. Also it would be important to determine their speech levels in residential settings or public environments (such as hospitals or office buildings) to aid in the development of speech privacy criteria.

4) Speech Intelligibility and Annoyance

The results in this study have been interpreted in terms of speech level (L_{eq}); with emphasis on the influence of background noise upon the speech as translated by the Articulation Index and correlated with a percentage of sentence intelligibility. However, no attempt was made to qualify sentence intelligibility with a subjective evaluation of the background level. Thus, a person might be able to communicate at 98% sentence intelligibility but be very annoyed with the kind of background noise or the ambient level. Such a qualification of the ambient level might be helpful in analyzing the difference between 95% sentence intelligibility and 99% intelligibility. Future research should concentrate on determining a relationship between the Articulation Index and sentence intelligibility and the subjective evaluation of noise.

III. BACKGROUND

At first glance, the literature on speech levels seems reasonably complete. Early studies such as Dunn and White (1940) established nominal levels observed under controlled conditions. Subsequent studies, such as those of French and Steinberg (1947) and Benson and Hirsch (1953) replicated the early findings with greater numbers of measurements taken under somewhat wider conditions.

From these studies come much of the data still considered as "standard" values of speech levels. For example, the widely accepted approximation of 60-65 dB (long term rms overall sound pressure level) at one meter for the level of a male talker reading prepared text aloud with normal vocal effort dates from these studies. Beranek's early (1947) work on speech communication, from which later measures such as SIL and PSIL are derived, also is based on these studies.

By the mid-1950's, some of the limitations of the early work had been recognized. The first deficiency of the data was that it was taken under quiet conditions. Normal conversations are not conducted exclusively in quiet background noise environments; people converse in noisy places as well. Thus, studies such as that of Korn (1954) were undertaken to quantify the relationship between the background noise in which speech is conducted with actual speech levels. Korn found that speech levels varied by 17.5 dB over a range of 50 dB in background noise. He concluded that the best estimate of the rate of increase of speech levels with background noise levels was

0.38 dB/dB. Korn's study had several methodological flaws, however, which encouraged further research in the area. Subsequent studies, such as those of Pickett (1958), Webster and Klumpp (1963), and Gardner (1966) have produced other estimates of the so-called "Lombard effect" (the tendency to raise the voice as the background noise increases) (Lombard, 1911).

A second deficiency was the absence of any real information on speech levels that people produce when not in controlled listening conditions. Under what conditions do people vary their vocal effort from a whisper to a shout? Are certain speech levels characteristic of certain social settings and background noise environments? How does speech intelligibility vary in these circumstances?

Thus, knowledge of speech levels was not wholly adequate several years ago, when EPA sought to identify noise "levels requisite to protect the public health and welfare with an adequate margin of safety". EPA based many of its recommendations for these health and welfare levels on speech interference effects, reasoning that speech interference was the most salient effect of noise exposure less intense than that associated with hearing damage, yet more intense than that associated with sleep interference. The basic phenomena of speech interference seemed well understood: speech spectra were well known; there was general if not detailed agreement on levels observed in controlled conditions; and several measures of speech intelligibility were well developed and in general use.

Upon closer examination, however, the gaps in the literature noted above became apparent. The most important lack was that of information on the statistics of distributions of speech levels encountered in the real world, beyond laboratory walls. The present research project was undertaken to provide more information on speech levels and thus to create a firmer basis for environmental noise criteria necessary for conversational speech.

IV. RECORDING PROCEDURE

Two different procedures were used to make recordings of speech levels. The first procedure was used for school classroom measurements, while the second was used in all other situations for measuring personal (face-to-face) communication. The main difference between the two procedures was in the number and placement of the microphones. The classroom situation used three microphones: two placed at different distances from the teacher, and one (a lavalier microphone) worn by the teacher. The second procedure utilized a miniature tape recorder and a single microphone located at the listener's ear while conversation was taking place.

A. Classroom

Typical microphone placement used in the classroom situation is indicated in Figure 1. In general, Position A measured speech and background levels near the front of the class approximately 2 meters from the teacher, while Position B (approximately 7 meters from the teacher) was used to record speech and background information at the rear of the class. All microphones including the one worn by the teacher were connected to a multi-channel tape recorder by long cords. This arrangement allowed the teacher normal freedom of movement about the classroom. The speech levels recorded with the microphone worn by the teacher were converted to equivalent levels, i.e., those that would have been measured one meter from the teacher's lips. Both teacher and students were encouraged to carry on the normal classroom procedures which

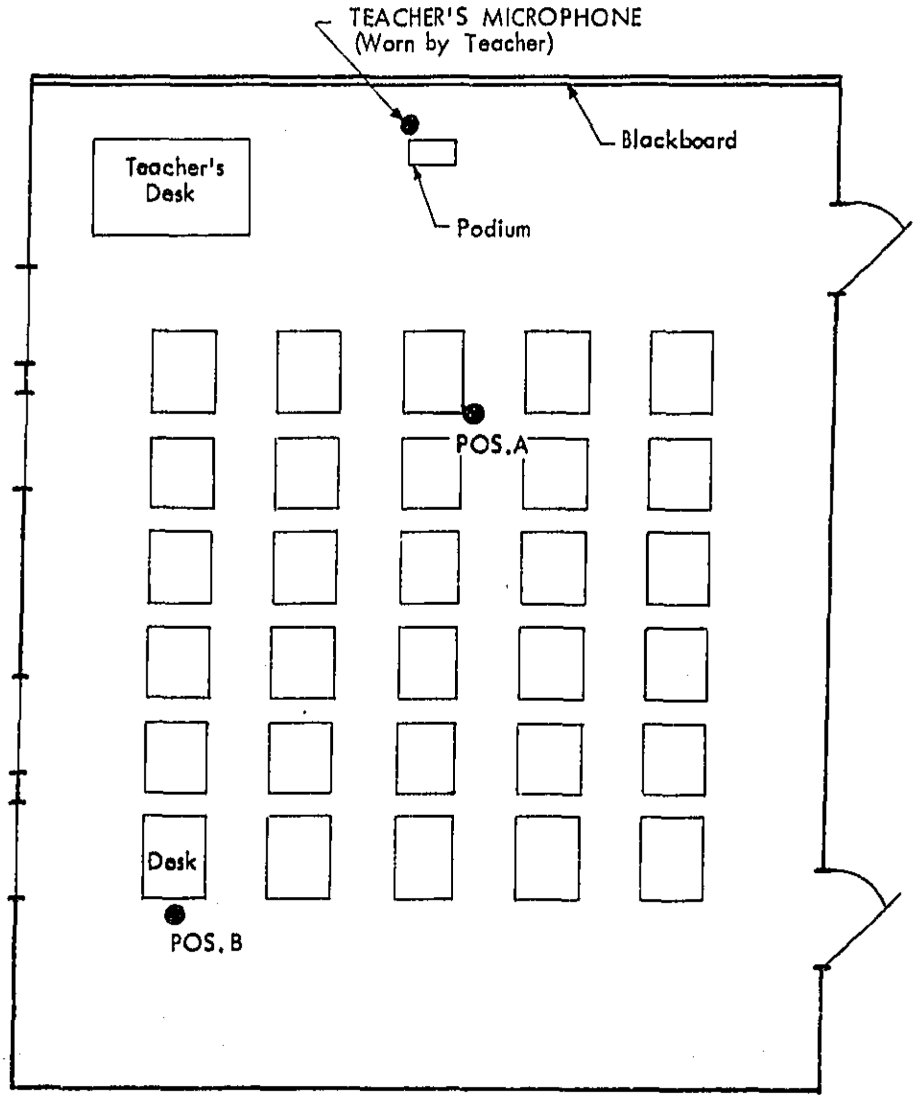

FIGURE 1. MICROPHONE LOCATIONS IN CLASSROOM

included 1) lecturing by the teacher, 2) question and answer interactions between teacher and class, and 3) study situations with no speech communication between teacher and class. Data reduction concentrated on speech levels collected during the teachers' lectures. Further detail on the instrumentation employed for all measurements is included in Appendix A.

A speech intelligibility test was given to the students in the classroom using phonetically balanced word lists. One of seven 50-word lists was read by the teacher, who was asked to read them in a customary classroom lecturing voice to the students. The students were asked to write the word heard on test sheets. The word lists were read in a fixed cadence, with no repeats. Complete instructions and word lists are included in Appendix B.

B. Individual Face-to-Face Communication

The procedure employed for all situations, other than schools, was to record normal conversation at fixed distances using a single microphone mounted near the ear on an eyeglass frame worn by a listener. Background measurements were made using the same equipment, but without conversation between the participants. Several recordings were made to obtain at least 10 seconds of continuous conversation of the talker alone without responses from the listener.

Because of the microphone location (very near the head), it was expected that the speech levels recorded were somewhat higher than would have been observed if the microphone had been placed away from the head. However, the measured speech levels were representative of those heard by the listener, and therefore provided reasonable levels for estimating the listener's intelligibility.

In all cases in the home measurement situations, there was no difficulty in conversing. This appeared to be true for most of the speech measurement environments except in the transportation vehicles where there was some difficulty in understanding speech. Initially speech measurements were made at the distance of one meter between the talker and the listener. However, in later measurement sessions, this restriction was relaxed, yet people seemed to voluntarily select this one meter communication distance, at least in the home environment. For transportation environments, this distance diminished to about 0.5 meter.

C. Anechoic Chamber Measurements

Measurements were made in an anechoic chamber one meter from the talker to determine speech spectra for men, women and children. The subjects were asked to repeat from memory the phrase "Joe took father's shoe bench out; she was waiting at my lawn." for approximately 10 seconds at different vocal efforts. The stipulated vocal efforts were labeled *Normal*, *Raised*, *Loud*, and *Shout*. Complete instructions are reproduced in Appendix B. In addition, a brief conversation between the experimenter and the subject was carried on before the formal test began; this speech was labeled *casual conversation*. During the *casual conversation* phase, the experimenter stood near the microphone at the one meter distance.

V. ANALYSIS PROCEDURE

The analysis was conducted with a one-third octave band real time analyzer interfaced to a digital computer, as discussed in Appendix A. All speech samples were at least 10 seconds in length, which allowed at least 100 samples to be taken at 0.1 sec. intervals. The spectrum analyzer's integration time was equivalent to "fast" on a sound level meter. Background noise analyses were completed in a similar fashion. All speech level and background data are reported in A-weighted sound pressure levels unless otherwise noted. All speech levels were corrected as necessary to account for possible background noise influence. To provide levels of vocal output at a constant distance, the speech levels were normalized to equivalent levels at one meter.

VI. MEASUREMENT SITE DESCRIPTION

A. Schools

Measurements were made in two schools. One was located on a moderately busy street while the other was situated on a quiet street under the landing path for Los Angeles International Airport. Since the noise from aircraft was lower than expected and since no background noise measurements included aircraft noise, the schools are referred to as I and II to avoid misinterpretation. Measurements were made in a total of 20 classrooms. Classrooms typically were occupied by 23 students. Windows in the classrooms were usually closed during the normal classroom activities.

B. Homes

Speech background measurements were made both inside and outside 25 homes. Some of the homes were located on quiet suburban streets and others were situated in areas of high traffic noise exposure. None of the homes were located under an airport landing path. Outdoor measurements were made in the backyard or patio areas not directly facing the street.

C. Hospitals

Measurements were made at 23 hospital locations in four medium sized hospitals. Speech and background measurements were made while conversing with patients in their rooms, and also while talking with on-duty nurses at nurses' stations.

D. Public Places

Speech background noise measurements were made at 19 locations in 7 large department stores while talking with on-duty sales personnel.

E. Transportation Vehicles

Recordings of speech and background levels were made while conversing with 11 passengers on the Bay Area Rapid Transit System (BART) in San Francisco. Speech level recordings of 12 passengers in 5 different commercial aircraft were also made. The measurement of speech and background levels for each passenger was made while the plane was cruising at its normal speed and altitude. Aircraft included Boeing 707s, Boeing 727s, Douglas DC-9s, a Lockheed L-1011, and a Lockheed Electra.

VII. RESULTS

A. Schools

A summary of the speech levels measured in the schools is shown in histogram form in Figure 2. The speech and background levels are given in A-weighted sound pressure level which was used exclusively in this report unless otherwise noted. The figure summarizes levels measured in the twenty classrooms at the two different schools, as well as at the three different microphone locations in the classroom represented by Positions A and B, and the teacher's microphone. The histograms indicate considerable variation in speech levels measured in different classrooms. The speech levels at school II for all microphone locations were higher on the average by 5 dB than those found in school I. Higher background levels (average 3 dB) were also noted for school II over school I. An analysis of the speech to background noise ratio for all microphone locations revealed that the teachers at both schools maintained about the same ratio. The average speech level was 15 dB higher than the background for school I and 16 dB for school II.

Figure 3 summarizes all of the teachers' speech levels measured with the teacher's microphone and normalized to one meter from the teacher's lips. The results indicate that the teachers' speech level in the range of 67 to 78 dB in the classroom increased at the same rate (1 dB/dB) as the background noise, over a range of 45 to 55 dB.

Figure 4 displays the results of the speech intelligibility tests administered in the classrooms. Articulation Indices (AI) based upon samples of the teacher's speech during class lectures were

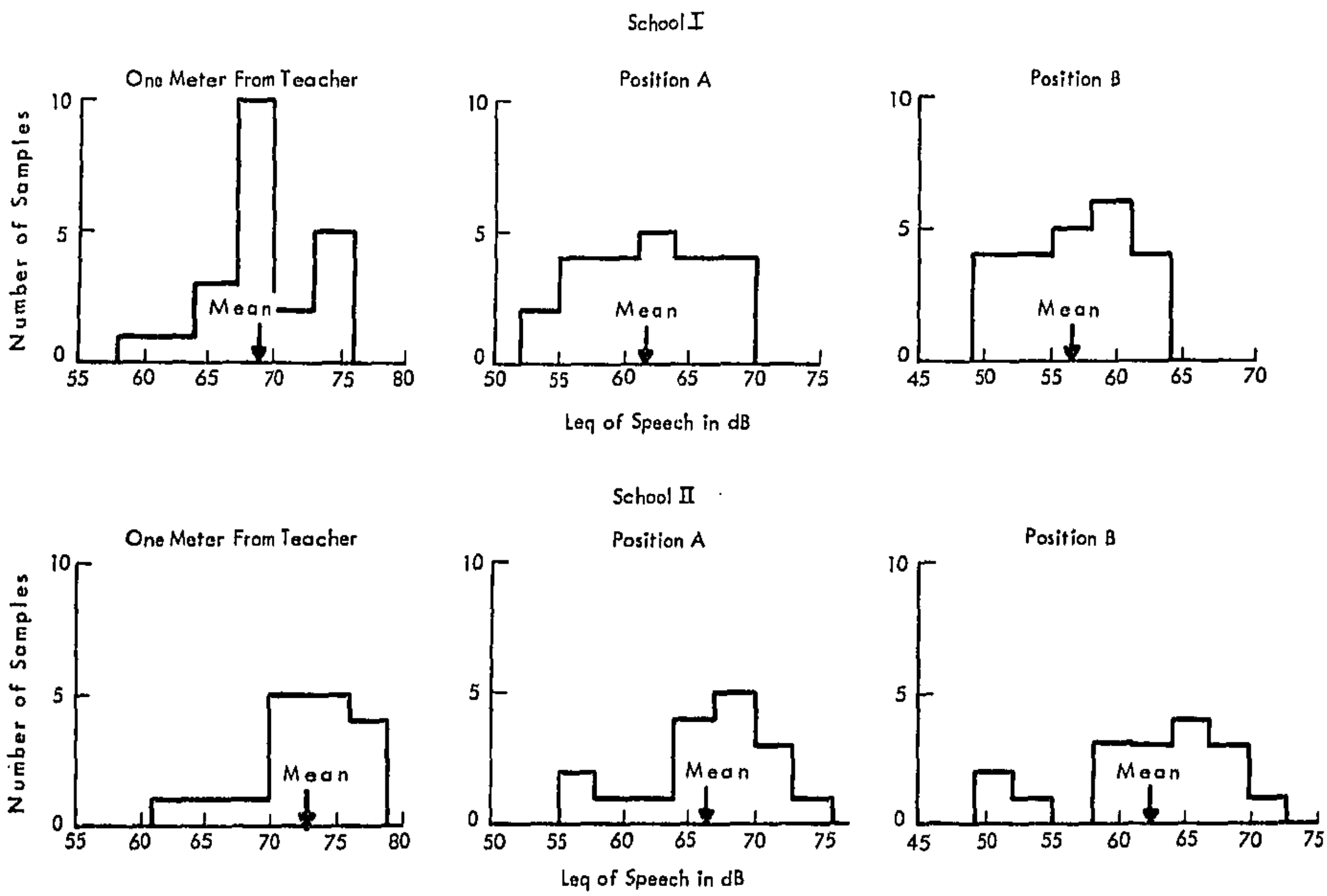

FIGURE 2. DISTRIBUTION OF SPEECH LEVELS IN SCHOOL PRODUCED BY TEACHERS ON SEVERAL OCCASIONS

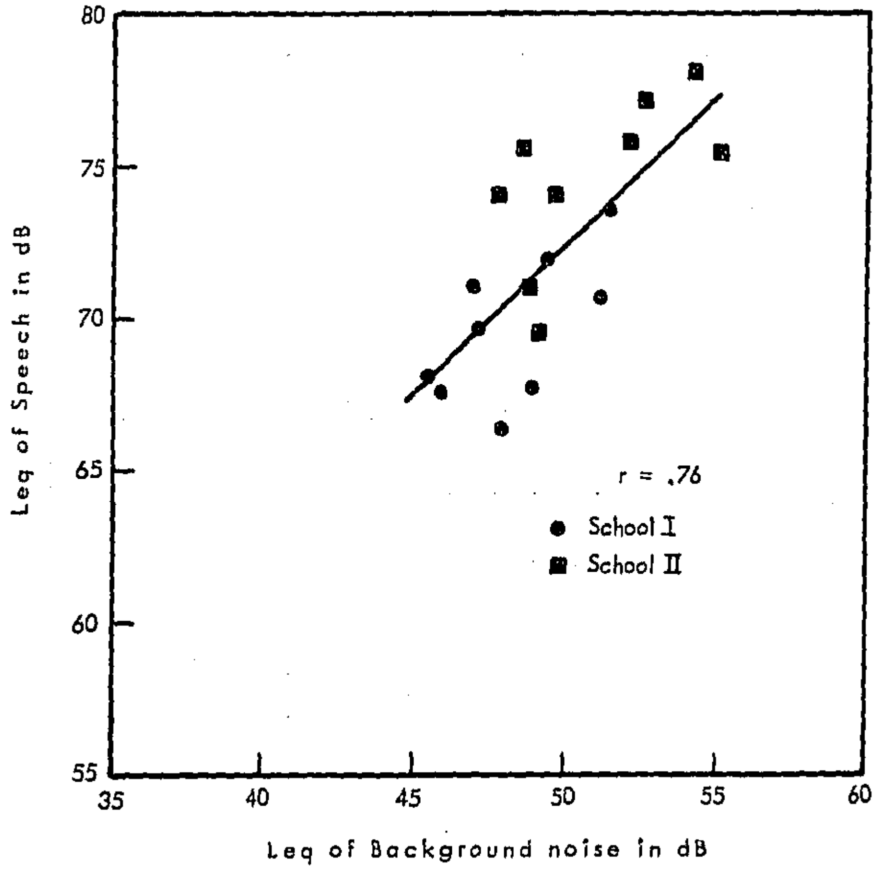

FIGURE 3. SPEECH LEVELS AT 1 METER PRODUCED BY TEACHERS DURING LECTURES

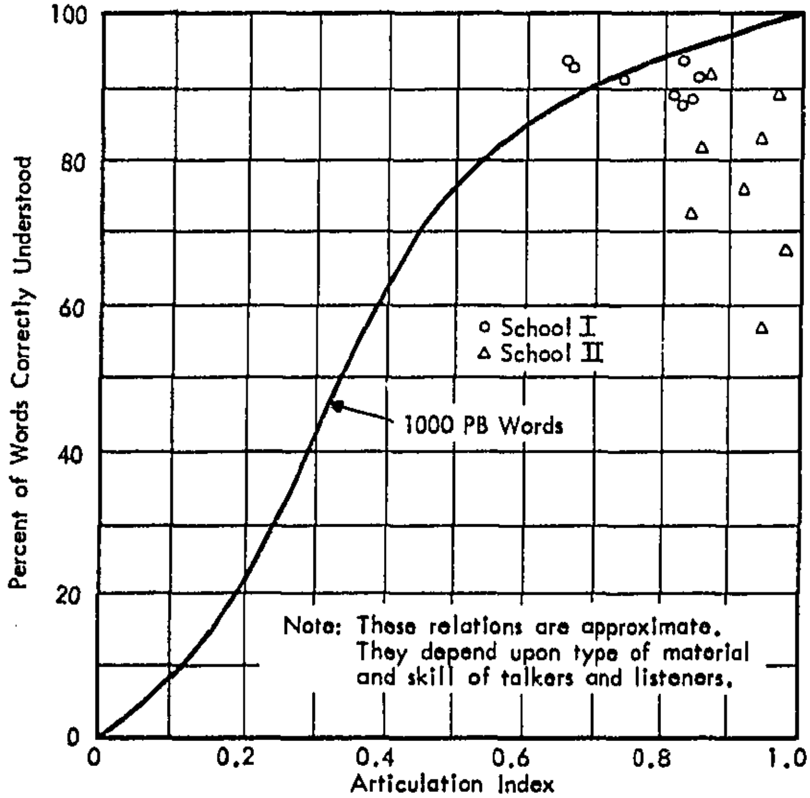

FIGURE 4. SPEECH INTELLIGIBILITY IN CLASSROOM

calculated and compared in Figure 4 to the percentage of correctly understood phonetically balanced words recited to the students during the intelligibility test. AI scores represent the percentage of speech material available to the listener; i.e., that which is not masked by background noise. The AI calculation uses the differences in one-third octave band levels between the speech and the background noise. This result is then weighted according to a procedure specified by ANSI (1969).

The results for school I are in good agreement with the relationship of percent correct versus Articulation Index given in the Articulation Index Calculation Standard (ANSI, 1969), represented by the curve in Figure 4. The average percent of words correct for school I is 91%. However, the results for school II were in minimal agreement with this curve and the average percent correct was only 77%.

B. Homes

Figure 5 shows the results of speech level measurements made in the homes. Speech samples were recorded both inside and outside homes which were located in suburban and urban areas. As indicated by the histograms, the average difference between the speech levels recorded inside the homes in the suburban or urban areas was 2 dB; whereas the difference in the observers' speech levels recorded outside the homes for the same areas was 10 dB. The higher speech levels were associated with the measurements in the urban areas.

As anticipated, higher background levels were found both inside and outside the homes in the urban areas. The average noise exposure level in the urban areas was 55 dB. This was 10 dB

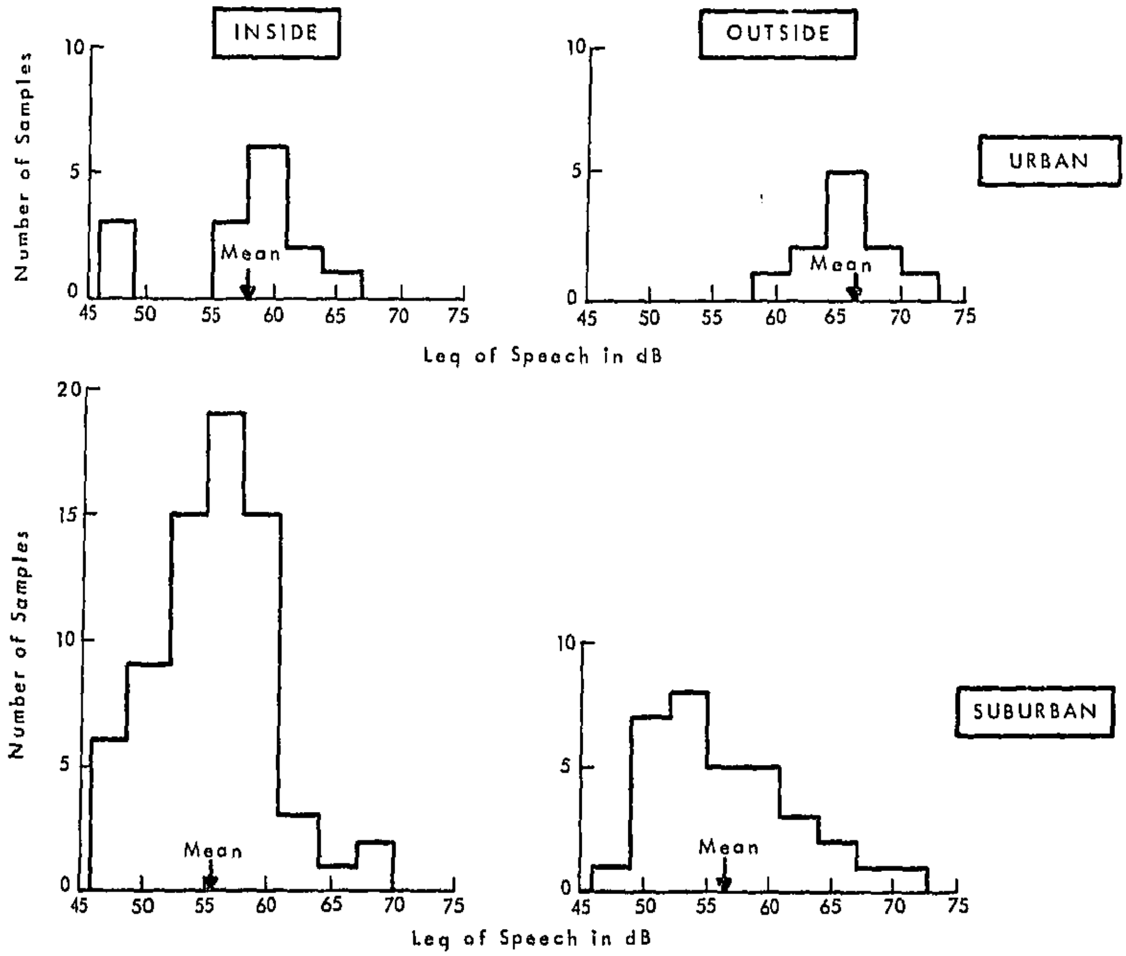

FIGURE 5. DISTRIBUTION OF SPEECH LEVELS AT HOMES PRODUCED BY PEOPLE ON SEVERAL OCCASIONS

higher than the average ambient in the suburban areas with 45 dB. A comparison of speech levels to background noise suggested that people maintain about a 5-8 dB speech to noise ratio when conversing outside their homes and a 9-14 dB speech to noise ratio when talking inside their homes. Thus, the intelligibility was maintained at a higher level inside rather than outside the homes.

Figure 6 illustrates the effects of background noise on speech level measured in the home. As the background noise level increased above a certain level (approximately 45 dB), in the homes, speech levels for the most part increased also. The lines connecting the points indicate that the same observer was recorded both inside and outside the home. The actual levels were then normalized to reflect what the speech level would have been if measured at 1 meter. As indicated by the horizontal lines in Figure 6 for background noise levels below 45 dB, speech levels measured either inside or outside the home remained the same. In some cases they remained the same up to a background level of 50 dB. However, in general, above a 45 dB background level the observers tended to raise their voice levels. Speech level tended to increase with background level above 45 dB, by about 0.5 dB for every 1 dB increase in background level.

Measurements were also made of television speech levels. The recordings were made with the microphone located at the observer's ear. Figure 7 shows a histogram of those levels with an average of 61 dB. The observers were told to adjust the television volume to their preferred listening level depending upon the distance they chose to sit from the television set. The average distance of observers from a television was 3 meters. A plot of television speech levels as a function of background noise is shown in Figure 8. This figure indicates that people increase the volume on the television 0.7 dB for every 1 dB increase in background level.

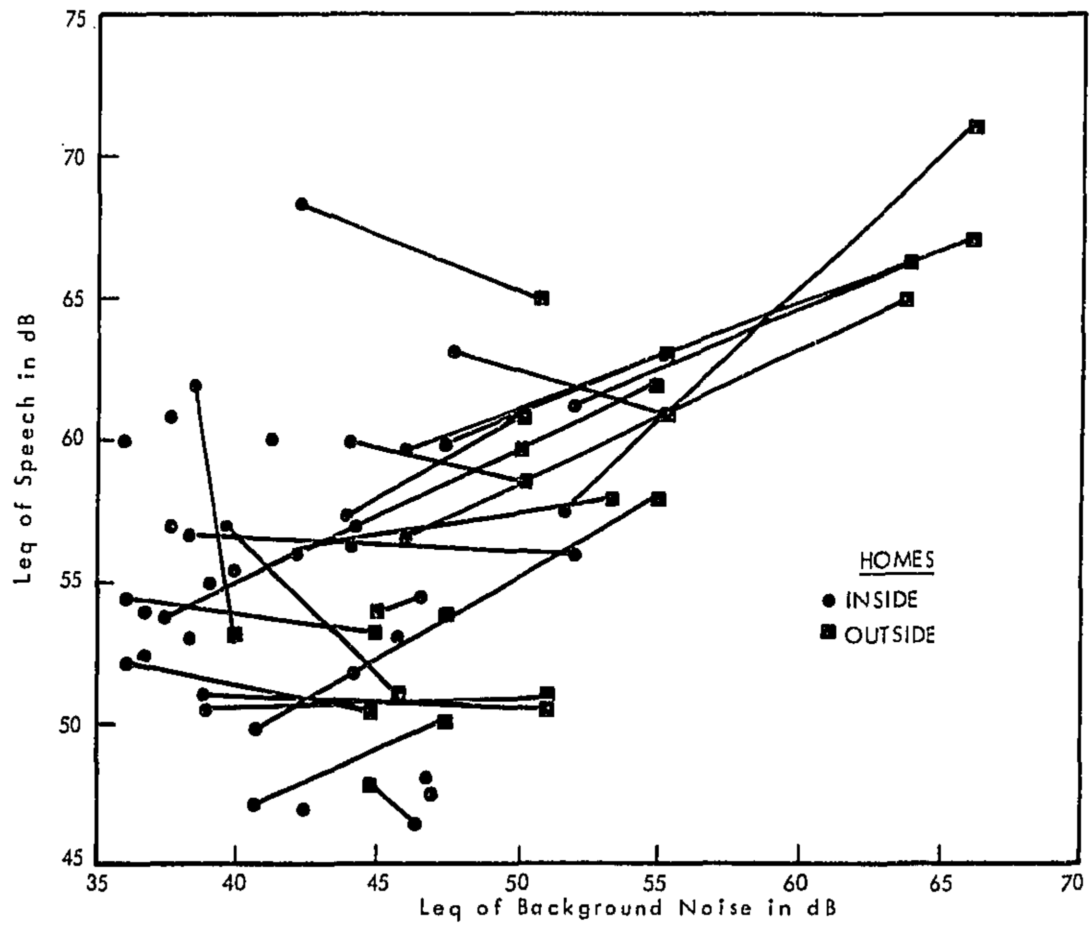

FIGURE 6. CONVERSATIONAL SPEECH LEVELS IN HOMES NORMALIZED TO 1 METER

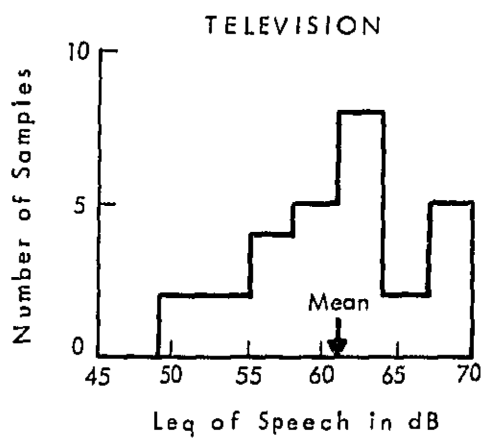

FIGURE 7. DISTRIBUTION OF TELEVISION SPEECH LEVELS AT VARIOUS DISTANCES

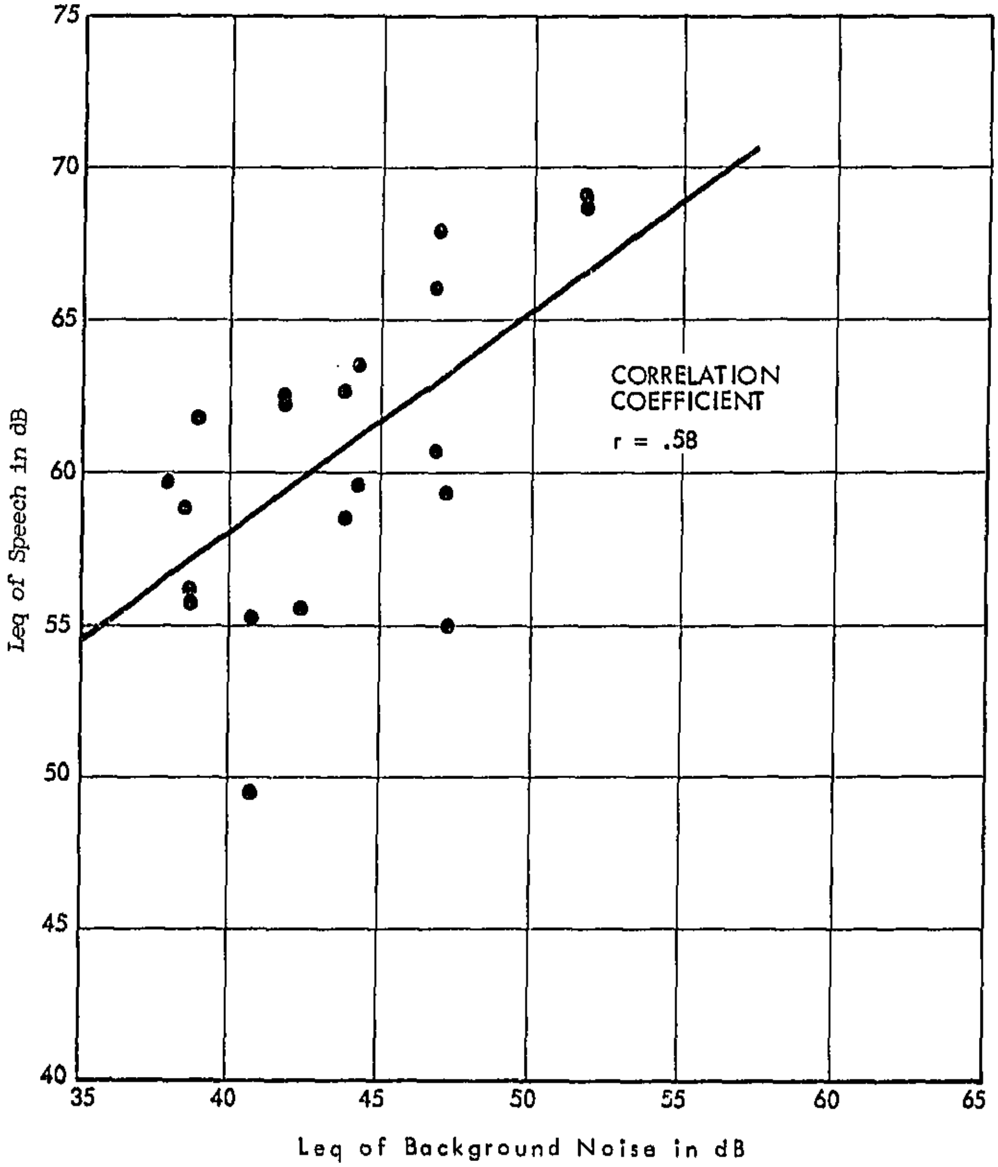

FIGURE 8. SPEECH LEVELS HEARD FROM TV AS A FUNCTION OF BACKGROUND NOISE

C. Hospitals

Conversational speech measurements were made for both nurses and patients in the hospital environment. Figure 9 shows these results in histogram form. The speech level for the patients was only 2 dB lower than the speech level for the nurses. At the nurses' stations there was only a 5 dB speech to noise ratio, as compared to the 10 dB speech to noise ratio found when measuring patients' speech in their hospital rooms.

D. Public Places

Speech measurements were also made in department stores. The histogram for speech level distributions in this environment is shown in Figure 10. The average speech level, measured at various distances from the listeners' ear, was 61 dB. The background level had an average of 54 dB, thus there was a 7 dB speech to noise ratio.

E. Transportation Vehicles

Speech levels were obtained for two types of transportation: trains (as represented by the San Francisco BART system), and conventional aircraft. Histograms of these speech levels are shown in Figure 11. The average speech level inside aircraft and trains averaged 75 dB, the average ambient level at 77 dB. The average distance between speaker and listener for both measurement situations was 0.4 meter.

F. Anechoic Chamber

Speech measurements were also made in a quiet laboratory setting in an anechoic chamber. Male and female talkers of all ages

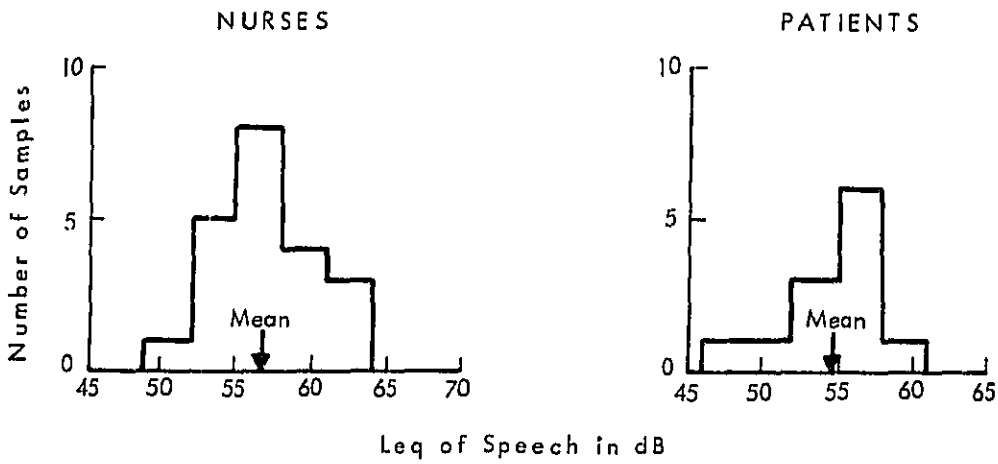

FIGURE 9. DISTRIBUTION OF SPEECH LEVELS IN HOSPITALS PRODUCED BY NURSES AND PATIENTS ON SEVERAL OCCASIONS

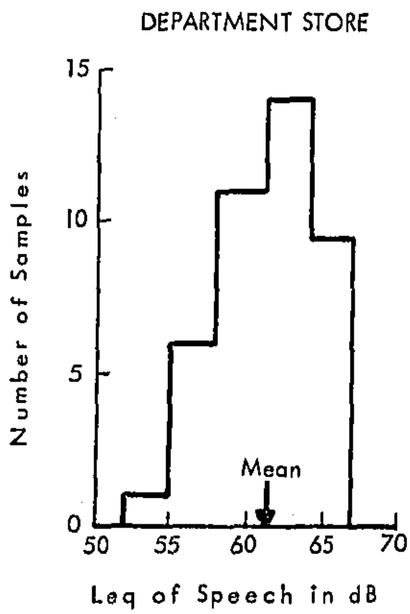

FIGURE 10. DISTRIBUTION OF SPEECH LEVELS IN DEPARTMENT STORES PRODUCED BY PEOPLE ON SEVERAL OCCASIONS

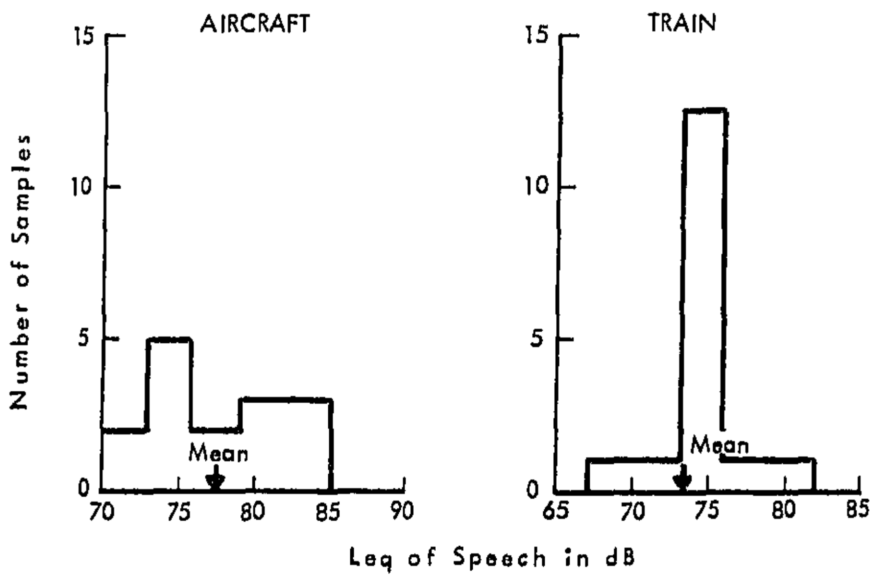

FIGURE 11. DISTRIBUTION OF SPEECH LEVELS IN TRAINS AND AIRCRAFT PRODUCED BY PEOPLE ON SEVERAL OCCASIONS

participated in this phase of the study. The range of ages for approximately 100 talkers was from 6 to 60 years, as shown in Figure 12. The average age was 24 years. The observers were grouped as males, females and children (talkers under age 13).

Histograms for the three groups and for the five different vocal efforts which were designated *casual, normal, raised, loud, & shout* are shown in Figures 13, 14 and 15. A summary of the means and standard deviations is found in Table I. For the categories *casual, normal & raised,* there was a small difference in measured voice level between the males, females and children. Larger differences in voice levels between male and female observer groups were found for the *loud* and *shout* categories. As expected, the males produced the highest average vocal output in the *shouting* and *loud* voice categories registering approximately 5 dB higher than the female group or the children.

The variability in voice level between talkers increased with vocal effort. For example, the voice level variability between male speakers for the *normal* vocal effort was 4 dB. But the difference between male speakers voice levels was more pronounced (7 dB) when instructed to recite Joe's Passage at a *shouting* voice level. A similar increase in speech level variability between speakers was also noted for both the female and childrens groups.

Figures 16 through 18 show a further analysis of this data in the plots of the voice spectra for males, females and children. The complete tabulation of all one-third octave band speech data recorded in the anechoic chamber can be found in the Data

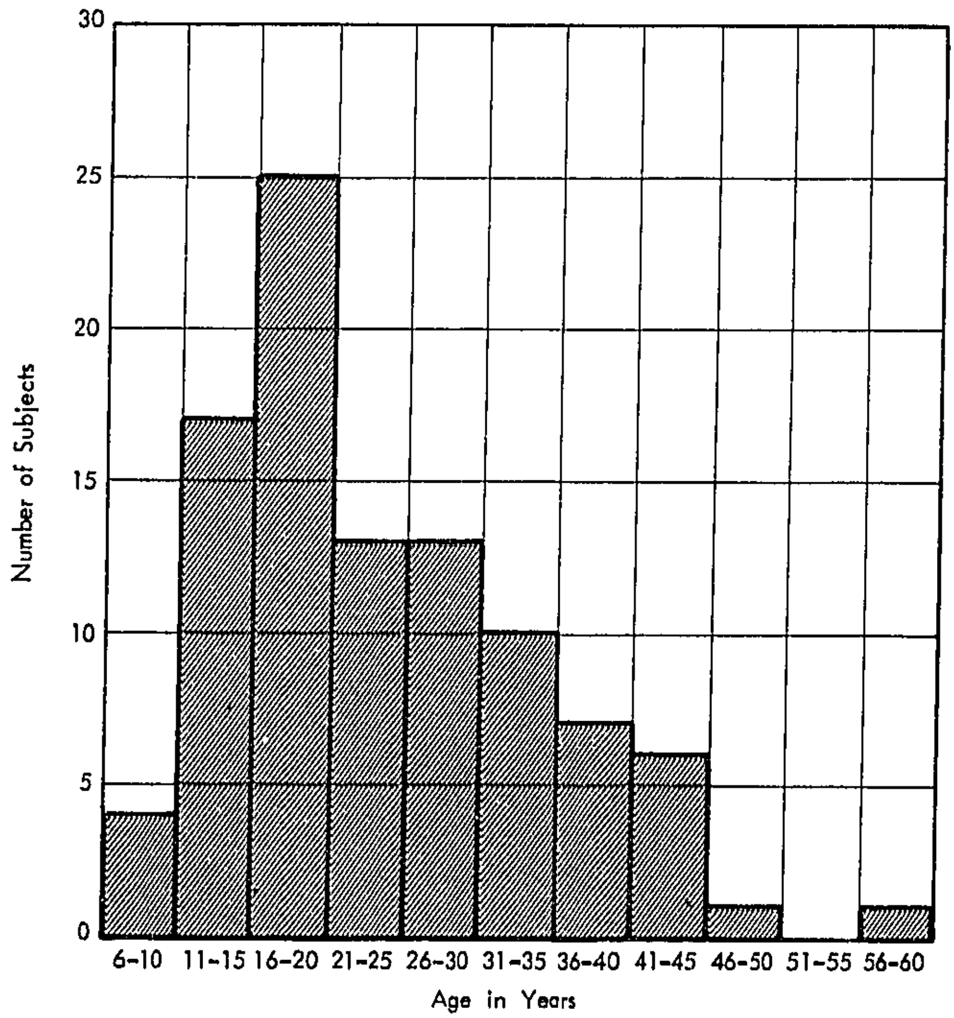

FIGURE 12. AGE DISTRIBUTION OF SUBJECTS EMPLOYED FOR ANECHOIC CHAMBER SPEECH MEASUREMENTS

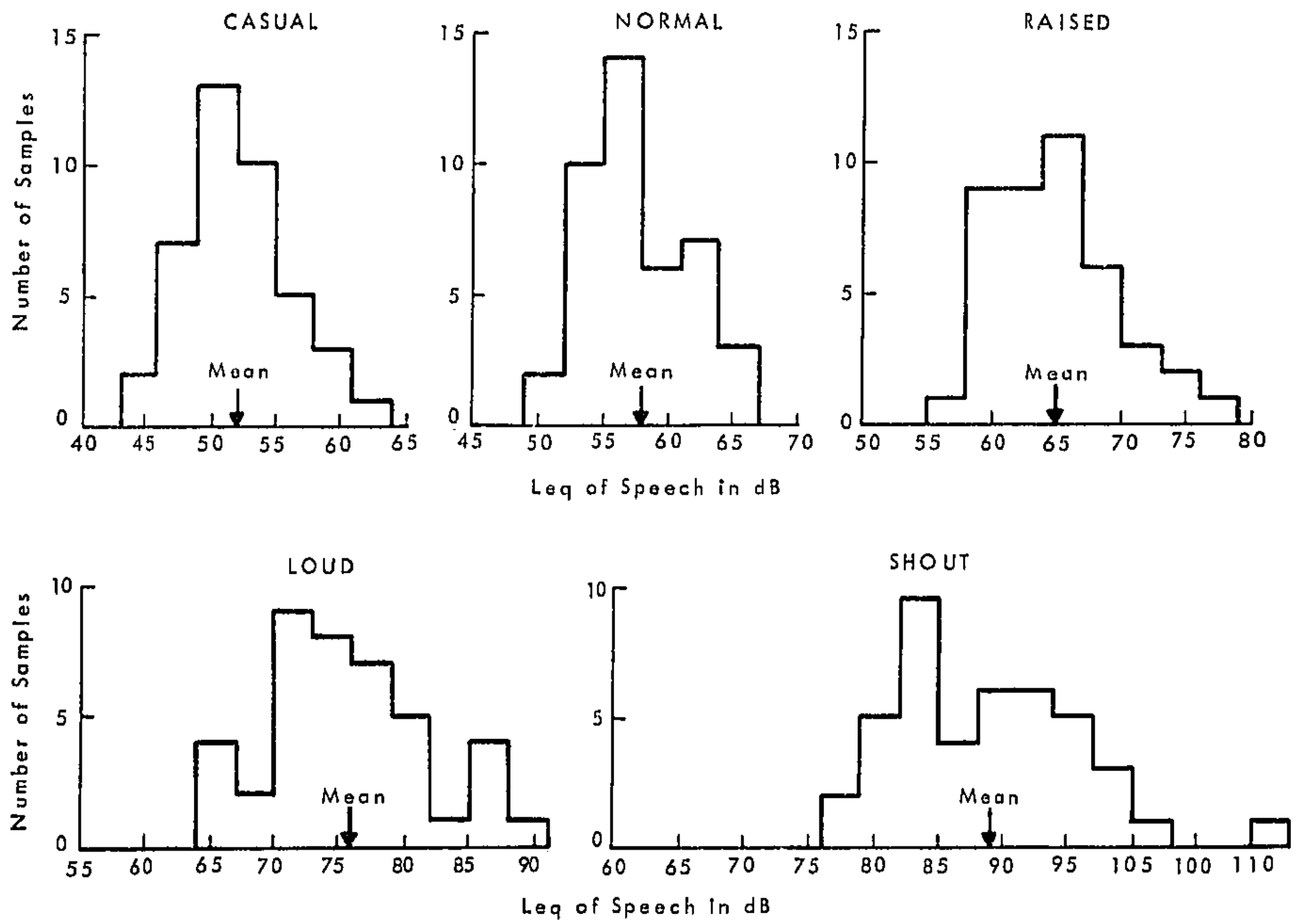

FIGURE 13. DISTRIBUTION OF SPEECH LEVELS PRODUCED BY MALES AT FIVE VOCAL EFFORTS

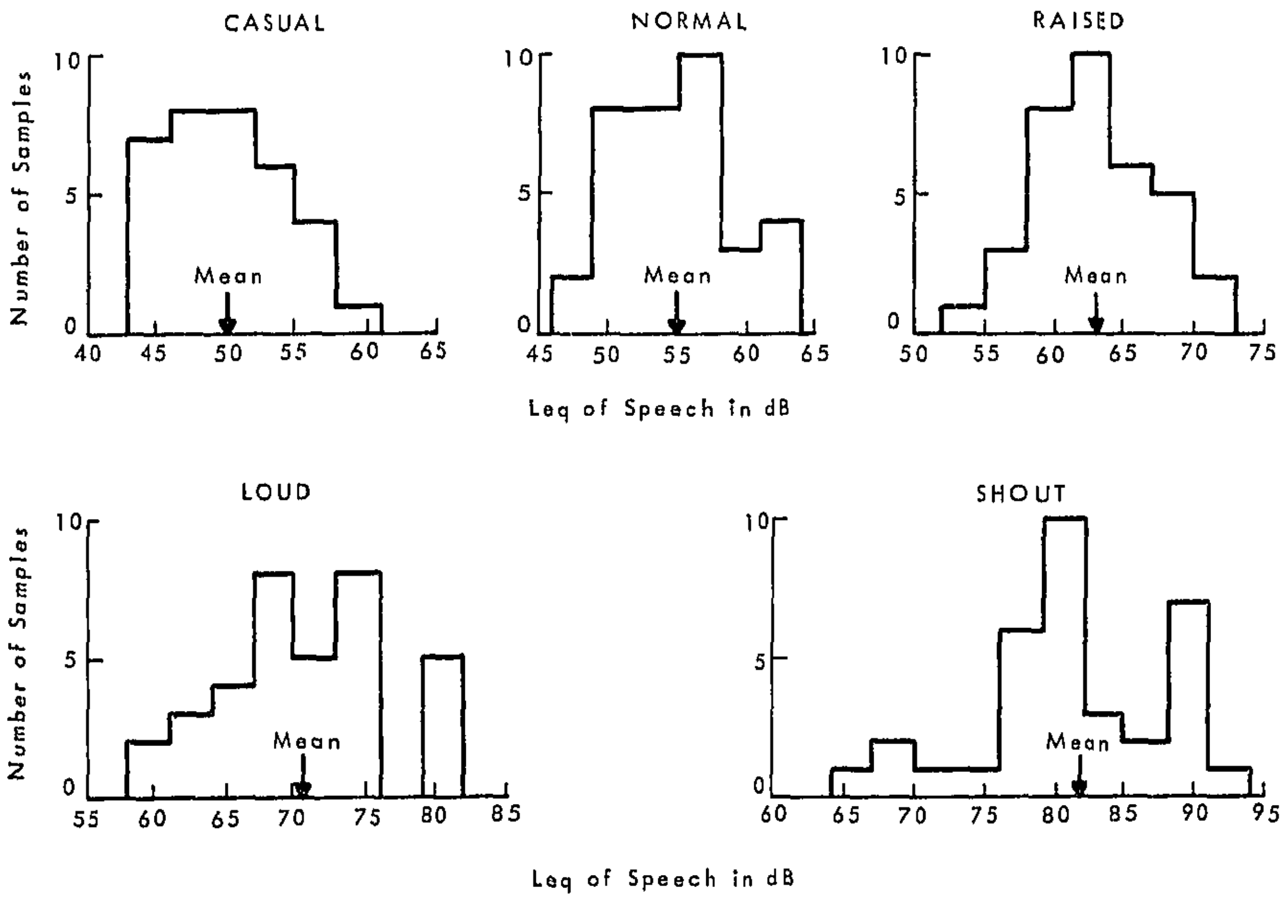

FIGURE 14. DISTRIBUTION OF SPEECH LEVELS PRODUCED BY FEMALES AT FIVE VOCAL EFFORTS

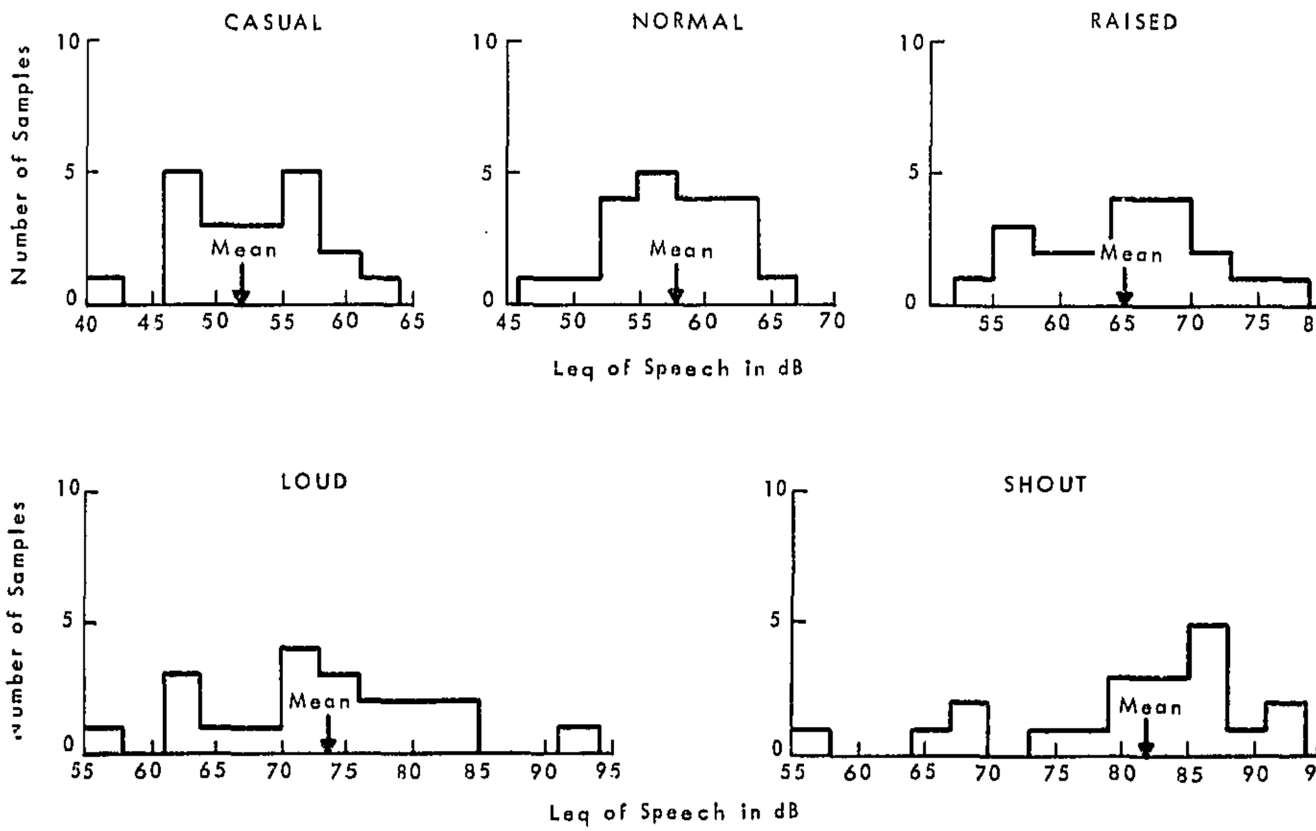

FIGURE 15. DISTRIBUTION OF SPEECH LEVELS PRODUCED BY CHILDREN AT FIVE VOCAL EFFORTS

Supplement for this report. The speech spectra across observers were relatively uniform in shape for increased vocal efforts; with a trend towards greater high frequency content at the higher voice levels. The main difference between male and female speech spectra can be noted in Figures 16 and 17, in the frequencies below 200 Hz. The spectra summarizing the results for male speakers (Figure 16) show a greater concentration of vocal energy in the one-third octave bands below 200 Hz. The speech levels at low frequencies, however, increased only slightly relative to the increased vocal effort. Furthermore, for all three groups, the levels at the low frequencies remained fairly constant.

The relationship between the overall level of speech and A-weighted sound pressure level was studied because the Articulation Index calculation procedure utilizes an overall measure of speech. The difference between the two measures was plotted as a function of A-weighted sound pressure level for all of the data collected in the anechoic chamber. A plot of these results is shown in Figure 19. A best fitting second order equation is provided for these data, as shown in the figure. Note that at high levels of speech, the average difference between A-level and overall level of speech is near 0, whereas at the lower levels (such as those associated with casual conversation) typical differences of 5 dB occur.

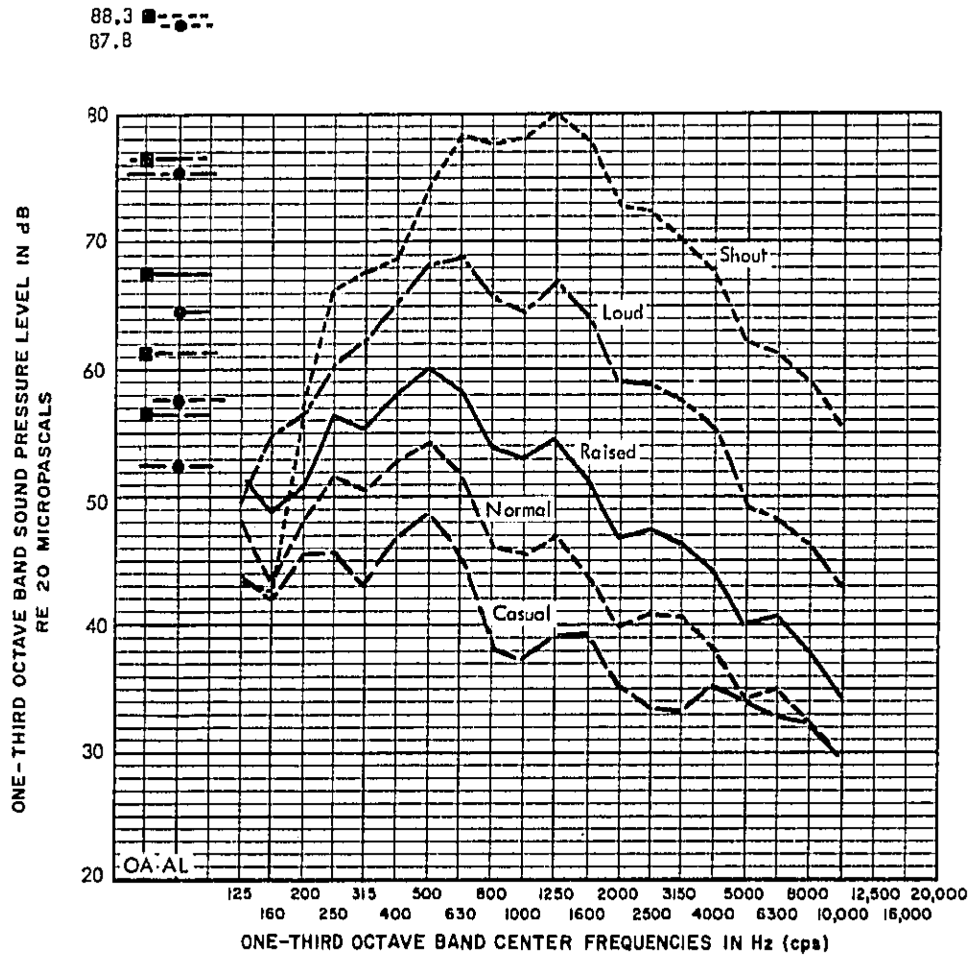

FIGURE 16. AVERAGE SPEECH SPECTRA FOR MALES AT FIVE VOCAL EFFORTS

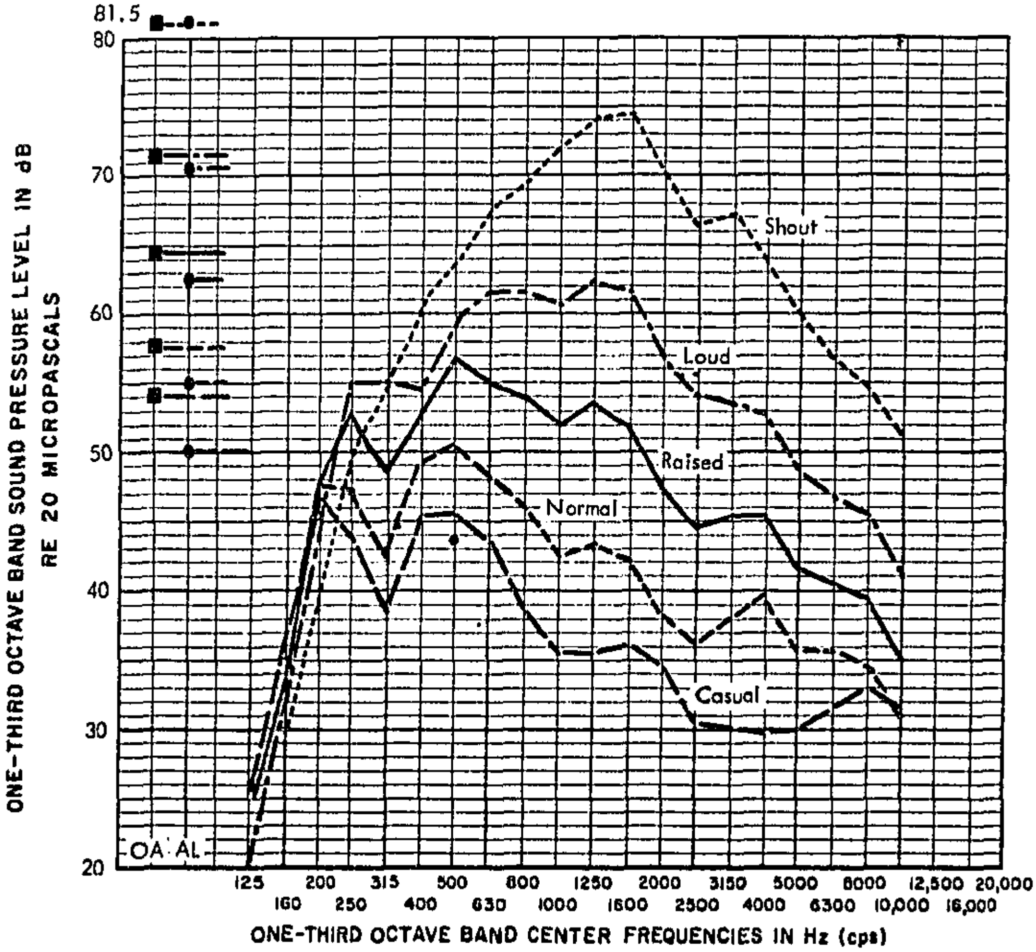

FIGURE 17. AVERAGE SPEECH SPECTRA FOR FEMALES AT FIVE VOCAL EFFORTS

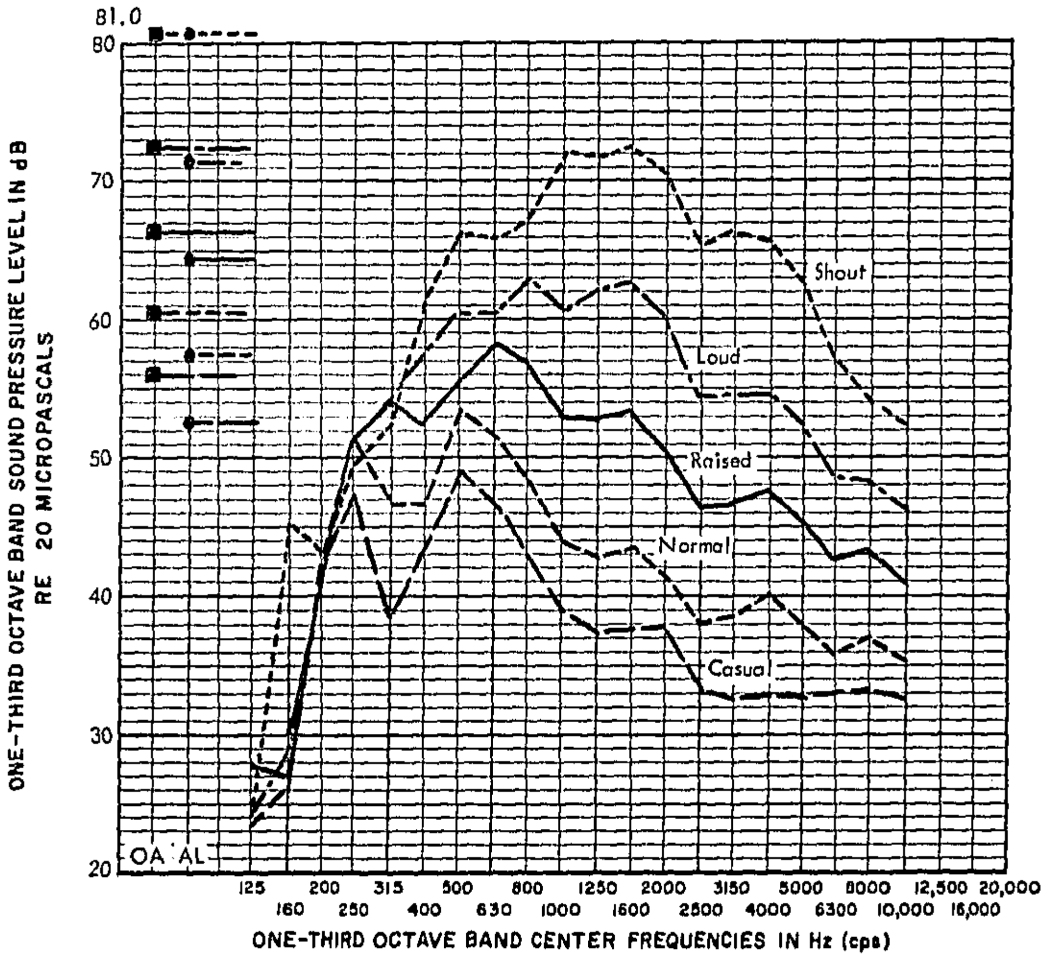

FIGURE 18. AVERAGE SPEECH SPECTRA FOR CHILDREN AT FIVE VOCAL EFFORTS

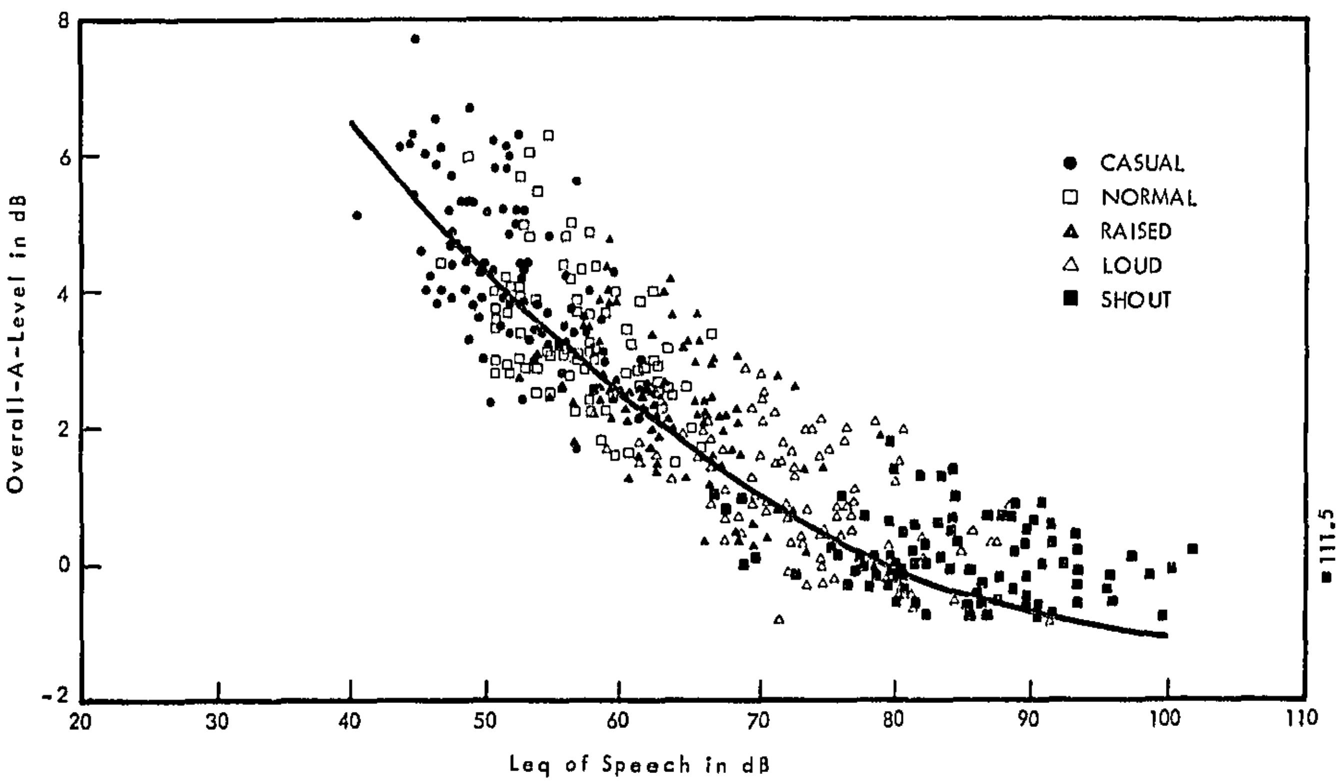

FIGURE 19. DIFFERENCES BETWEEN OVERALL AND A-WEIGHTED SOUND PRESSURE LEVELS OF SPEECH

VIII DISCUSSION

A. Lecturing in Schools

The average speech level computed for all teachers (normalized to 1 meter) was 71 dB. This was compared to the other speech measurement situations. This level was 13 dB greater than the average voice level (normalized to 1 meter) employed either inside or outside the home. The teachers' voice levels were also compared with the laboratory study of speech measured in the anechoic chamber. As noted in Table I, the 71 dB average voice level for the teachers would fall between the *raised* and *loud* vocal effort.

The increase in background level had a noticeable effect on the teachers' vocal efforts. The speech level increased with background level at 1 dB/dB whereas for all other speech measurement situations the rate was 0.6 dB/dB (Figure 20). Over one-quarter (28%) of the teachers sampled spoke at an average voice level of 75 dB or more. All of these were teachers measured at school II. The average lecturing level at the back of the classroom (Position B-estimated at 7 meters from the teacher) was also measured for all teachers in both schools and was 60 dB.

The increase in voice level did not seem to help performance in the word intelligibility test given to the students. Thus, even though the teachers' speech levels at school II were on the average 5 dB higher than that used at school I, the students in school I achieved 14% better scores on their word intelligibility test. A possible explanation is that the students in school II lacked the motivation to adequately perform on this test.

It is important to mention also that although the sites for the school were selected as being representative of a traffic

TABLE I

SPEECH LEVELS (dB) AT VARIOUS VOCAL EFFORTS MEASURED IN AN ANECHOIC CHAMBER* (BACKGROUND LEVEL L_{eq} = 16 dB)

	MALE		FEMALE		CHILDREN		AVERAGE
VOICE LEVEL	L_{eq}	σ	L_{eq}	σ	L_{eq}	σ	L_{eq}
Casual	52.0	4.0	50.0	4.0	53.0	5.0	52.0
Normal	58.0	4.0	55.0	4.0	58.0	5.0	57.0
Raised	65.0	5.0	63.0	4.0	65.0	7.0	64.0
Loud	76.0	6.0	71.0	6.0	74.0	9.0	73.0
Shout	89.0	7.0	82.0	7.0	82.0	9.0	85.0

*Results were rounded off to the nearest decibel.

noise environment and an aircraft noise environment, the main source of background noise, particularly in the aircraft exposed school, was produced by the students themselves in the classroom.

B. Conversing in Various Environments

The means and standard deviation of the speech levels measured under non-laboratory conditions are summarized in Table II. These data reflect speech and background levels measured under conditions, as judged by the observers, of adequate speech intelligibility. These conditions take into consideration, among other variables, the distance between the talker and the listener, the visual cues and the length of the conversation. Thus, for conversations recorded in high background noise environments (above 70 dB), such as trains or airplanes, the distance of 0.4 meters between the participants was shorter than between participants recorded in quieter environments such as the home where the distance was approximately 1.0 meter. Communication in the high ambient environment also necessitated careful attention to the speakers' phraseology in addition to visual cues to achieve adequate intelligibility.

The spread in speech levels between talkers and between speech samples was considered. The average variability of speech levels computed from the speech samples collected from each talker in the home was approximately 2 dB, as compared to an average standard deviation of 5 dB between talkers for speech measured in the home. The variability between talkers for the laboratory condition designated as *casual, normal & raised* ranged from 4 dB to 7 dB (Table I). The intertalker variability in speech levels increased even more when the talkers spoke at a *shouting* level (ranging from 7 to 9 dB).

TABLE II

AVERAGE SPEECH LEVELS IN VARIOUS ENVIRONMENTS[1]

		Background Levels (dB)		Speech Levels, dB					
				1 Meter		Pos. A 2 Meters		Pos. B 7 Meters	
		L_{eq}	σ	L_{eq}	σ	L_{eq}	σ	L_{eq}	σ
Schools -	I	48.0[2]	2.0	69.0	4.0	62.0	5.0	57.0	4.0
	II	51.0[2]	3.0	73.0	4.0	66.0	5.0	62.0	6.0
				Corrected To 1 Meter		Conversation Distance			
Homes -									
Outside	Urban	61.0	5.0	65.0	4.0	66.0	4.0		
	Suburban	48.0	4.0	55.0	5.0	56.0	5.0		
Inside	Urban	48.0	2.0	57.0	6.0	57.0	6.0		
	Suburban	41.0	3.0	55.0	5.0	55.0	5.0		
Hospitals -	Nurses	52.0	5.0	56.0	3.0	57.0	4.0		
	Patients	45.0	2.0	56.0	2.0	55.0	1.0		
Department Stores		54.0	4.0	58.0	3.0	61.0	3.0		
Trains		74.0	3.0	66.0	2.0	73.0	3.0		
Aircraft		79.0	3.0	68.0	4.0	77.0	4.0		

[1]Results were rounded off to the nearest decibel.

[2]Measurements were made with typical student activity. Background values of classrooms during the phonetically balanced word test and other "quiet periods" were 47 for School I and 43 dB for School II.

The measurement of speech levels in face-to-face communication revealed a corresponding increase in speech level as background levels rose above 45 dB. Figure 20 summarizes this effect for all of the speech levels measured in a two-way communication situation. The points are coded for the type of environment. While all the speech measurements were not taken at the same distance for all speakers, the criteria of adequate observer assessed intelligibility was maintained.

Regression lines were computed for the data plotted in Figure 20. An approximation of the regression line was also drawn. This approximation falls well within the confidence interval of the regression lines. The results for this study suggested that for background levels below 45 dB, the level at the listener's ear remained constant at 55 dB. Thereafter, the speech level increased up to approximately 80 dB at a rate of 0.6 dB/dB increase in background level which ranged from 45 to 81 dB.

By utilizing Table I & II, it was possible to compare the results from the face-to-face speech measurements to the data collected under laboratory conditions in the anechoic chamber. The *casual* conversation measure was conducted in a manner similar to the face-to-face communication situation, only in a controlled background level of 16 dB in the anechoic chamber. The average speech level measured for all observers under this laboratory condition was only 3 dB below the speech levels obtained at 1.0 meter in the suburban home environment. The average speech level obtained for observers speaking in a *normal* voice in the chamber was 57 dB, only 2 dB higher than the quiet home situation.

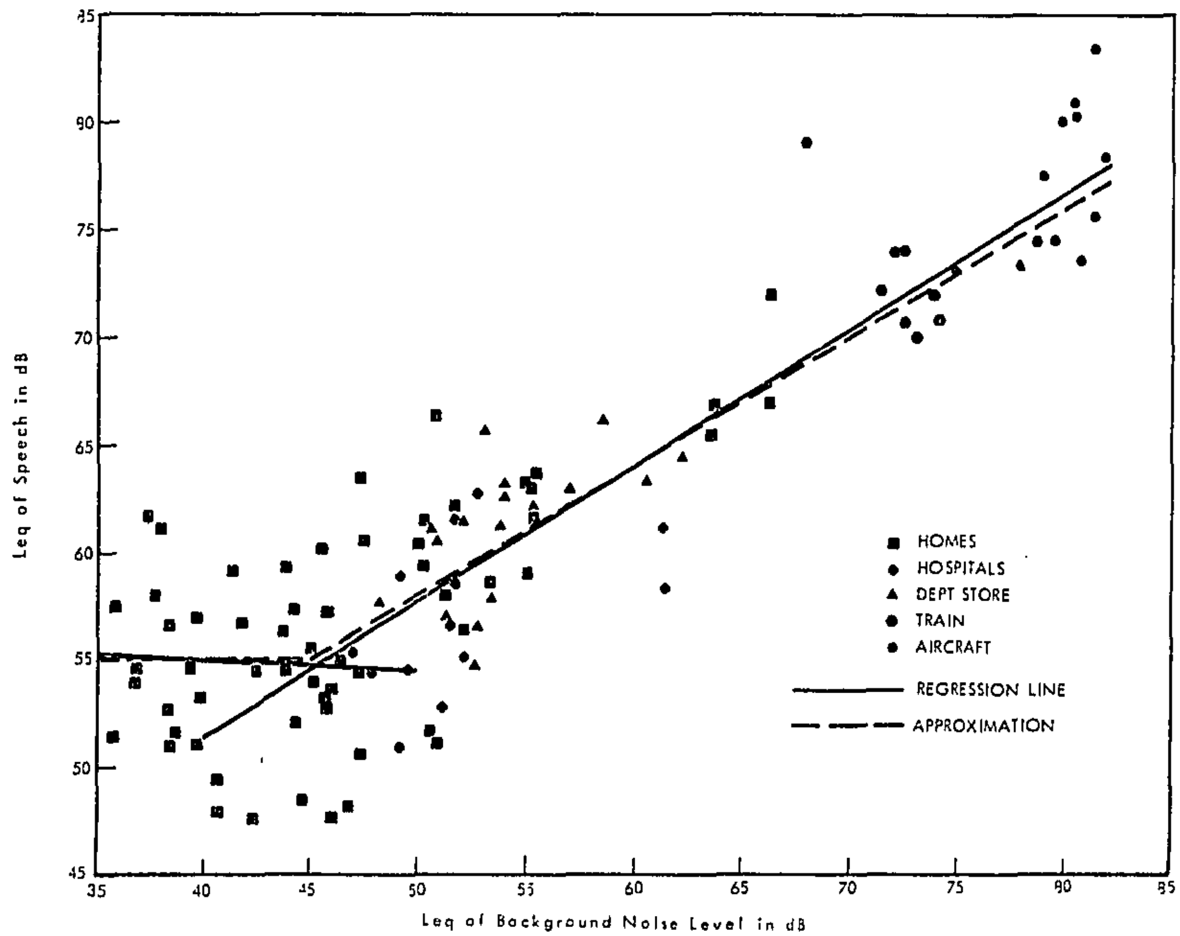

FIGURE 20. CONVERSING SPEECH LEVEL AS A FUNCTION OF BACKGROUND NOISE IN SEVERAL ENVIRONMENTS

In Figure 21, a more precise comparison was made between speech results obtained in the anechoic chamber and those collected under non-laboratory conditions. The speech levels measured in the different noise exposure situations were originally recorded at varying distances, however for this analysis, all results were adjusted to approximate speech levels measured at 1.0 meter. It was noted from this plot that speech levels used in the homes and hospital and department stores could be characterized as *casual* to *normal* voice levels, as determined from the anechoic chamber measurements. People in transportation interior environments such as trains or aircraft appeared to speak at what could be compared to *raised* or *loud* voice levels in the laboratory situation.

Three regression lines were calculated for the data plotted in Figure 21. An approximation of the three regression lines was also drawn in Figure 21. This simplified relationship indicated that speech level stayed at about 55 dB when background levels were below 48 dB. This is only a 3 dB increased difference in background level from results in Figure 20, where speech levels were plotted disregarding distance between speakers. It is noted in Figure 21 that people started raising their voice level after 48 dB and continued to do so at the rate of 0.6 dB/dB increase in the background level. At an ambient of 70 dB, the speech data appeared to level out at 67 dB which indicated that most people stopped raising their voice above a 70 dB ambient. An explanation for the dramatic difference between Figures 20 and 21 in the speech measurements above 70 dB background level, was that the high levels measured at the listener's ear and plotted in Figure 20 were due to the short distance between the speaker and the listener and not necessarily increased voice level due to

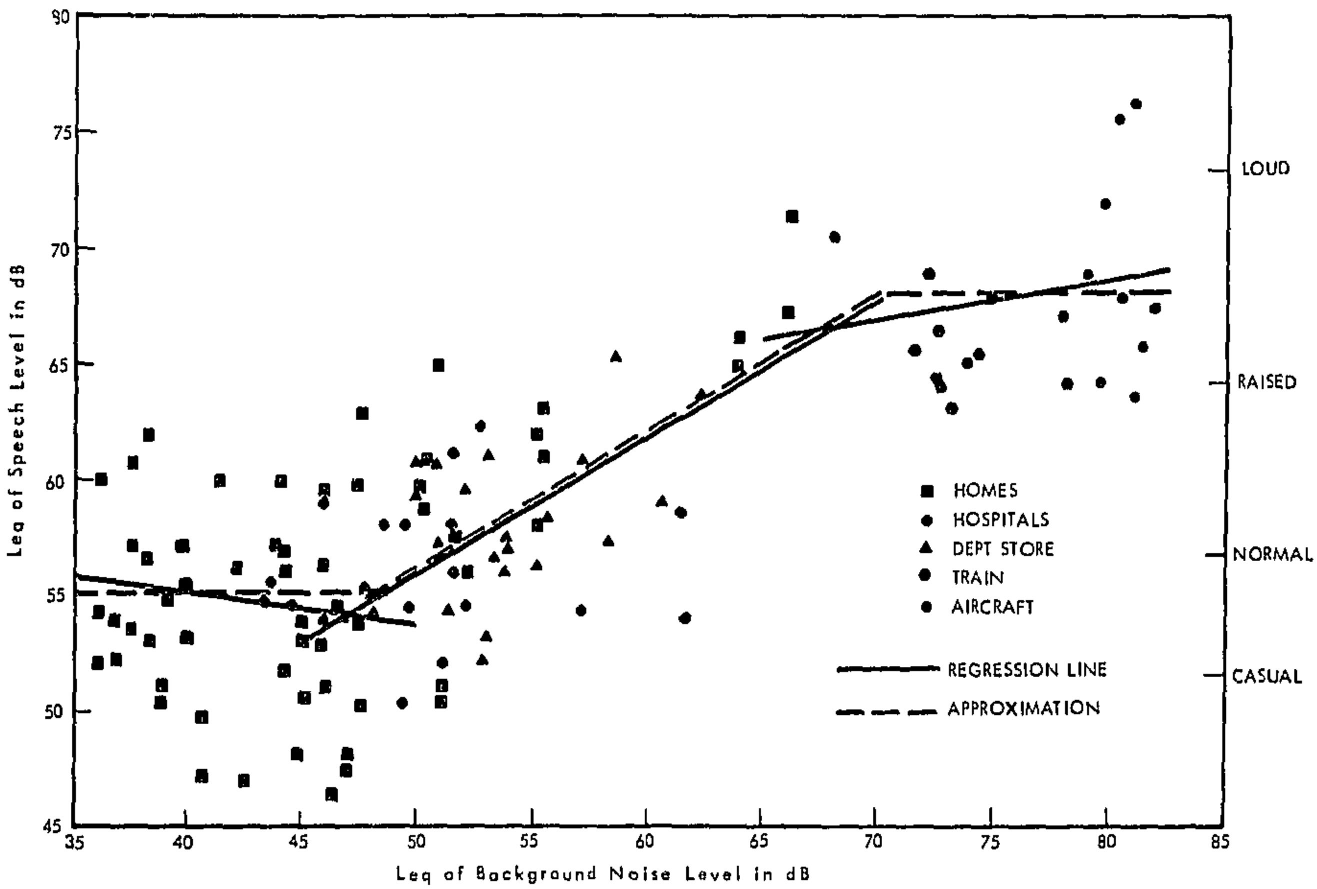

FIGURE 21. CONVERSING SPEECH LEVEL NORMALIZED TO ONE METER AS A FUNCTION OF BACKGROUND NOISE IN SEVERAL ENVIRONMENTS

increased background level. Therefore in Figure 21 when the levels were adjusted for the same 1.0 meter distance, 86% of the speech measurements taken in an ambient environment above 70 dB dropped below the 70 dB speech level.

A plot of the interpersonal communication distance between speaker and listener as a function of the background level is seen in Figure 22. As the slope of the line indicates, the distance between the participants in the quieter environments such as homes or hospitals was approximately 1.0 meter. The average background level corresponding to this distance was 43 dB. When the background level increased to 70 dB such as in the transportation environments, there the distance between the participants decreased to 0.5 meters.

A subjective determination of speech intelligibility was not the sole criterion. Speech intelligibility was also defined objectively by the Articulation Index (ANSI, 1969). The relationship between AI and background level is seen in Figure 23. The correlation coefficient for the regression line drawn through this data was r =-0.82. Reading from the slope of the regression line, at the background level of 40 dB, the AI = 0.82. For an increased ambient level of 70 dB, the AI = 0.44. Thus, it was observed that as the background level increased, the Articulation Index decreased.

The curve plotted in Figure 24 is a translation of the regression line in Figure 23. This was achieved by converting the Articulation Indices into speech intelligibility scores taken from the psychometric function which describes the percentage of sentences

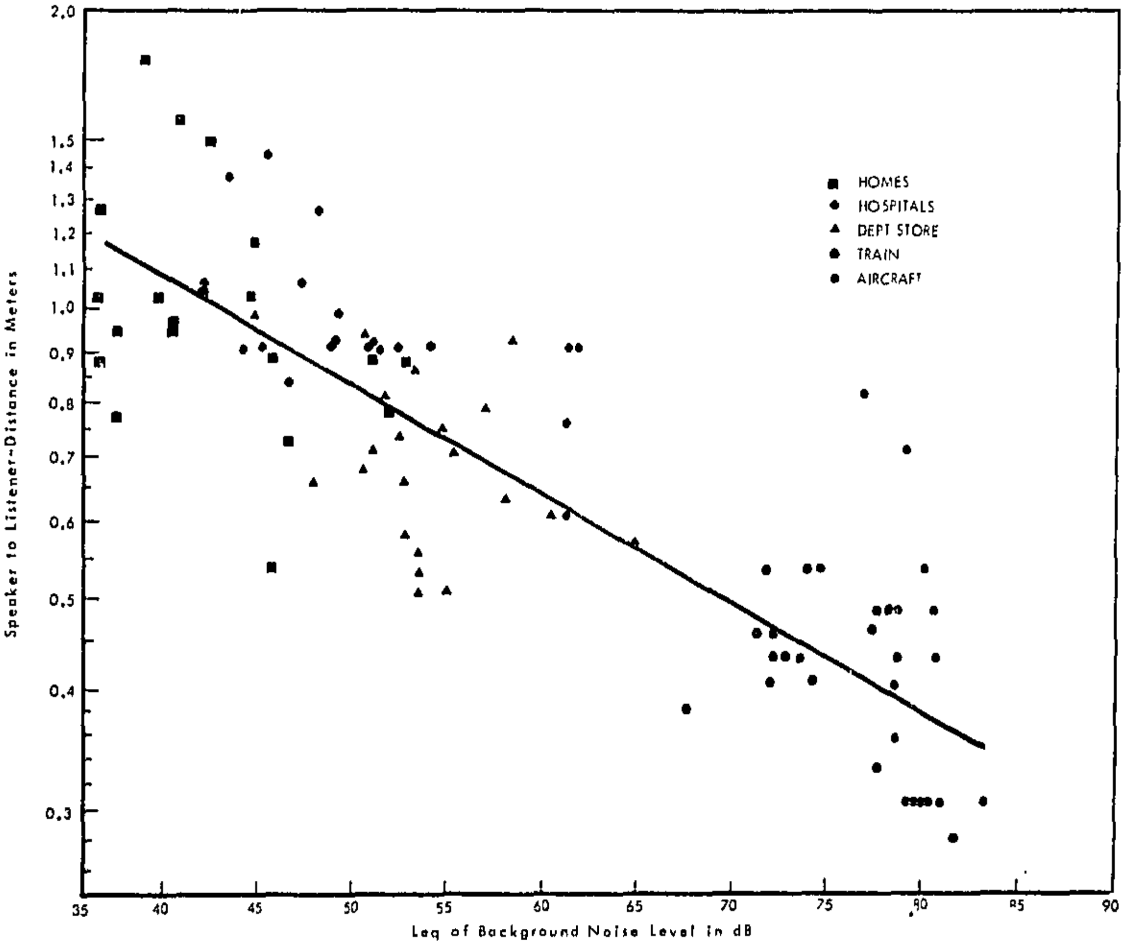

FIGURE 22. INTERPERSONAL DISTANCE OBSERVED FOR CONVERSATIONS AS A FUNCTION OF BACKGROUND LEVEL IN VARIOUS ENVIRONMENTS

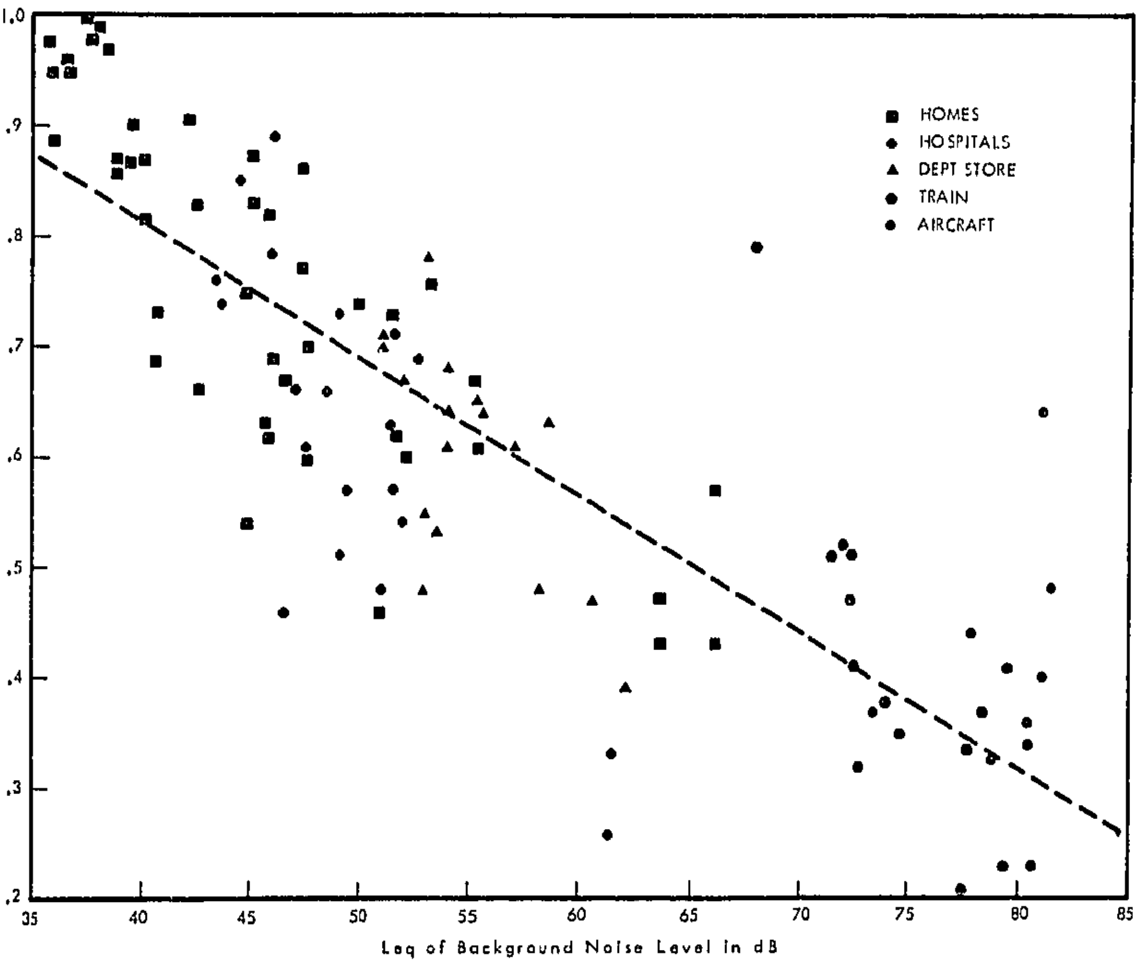

FIGURE 23. ARTICULATION INDEXES FOR CONVERSATIONS IN VARIOUS ENVIRONMENTS

correctly understood (ANSI, 1969). Thus, for an AI = 0.50 the sentence intelligibility score is 97% and this occurs at a background of 65 dB. This curve can now be utilized to predict sentence intelligibility given an ambient level. For example, at an ambient of 80 dB, the sentence intelligibility score was 81%.

A detailed comparison was made of the Articulation Indices and sentence intelligibility scores for the speech levels utilized in the five environmental situations with decidedly different background levels. As representative of the quiet environments, the average AI for homes was 0.71 with virtually 100% sentence intelligibility; and for hospitals the AI = 0.63 with 99% intelligibility. As the background level increased above 45 dB, the Articulation Index decreased. Thus, for department stores the AI = 0.61 with 98% intelligibility; for trains the AI = 0.44 with 94% sentence intelligibility; and for airplanes the AI = 0.38 with 90% intelligibility. Thus, it was apparent that intelligibility was inversely correlated to background levels. However, the decrease did not impede communication until the background level was above 70 dB, then the AI dropped two-tenths to AI = 0.44 and sentence intelligibility was calculated at less than 95%.

C. Speech Measurements in an Anechoic Chamber

Table I summarizes the results of the anechoic chamber measurements. There was approximately a 30 dB difference between the average voice levels designated *casual* and *shout*. But the progressive increase in level for the five speech categories

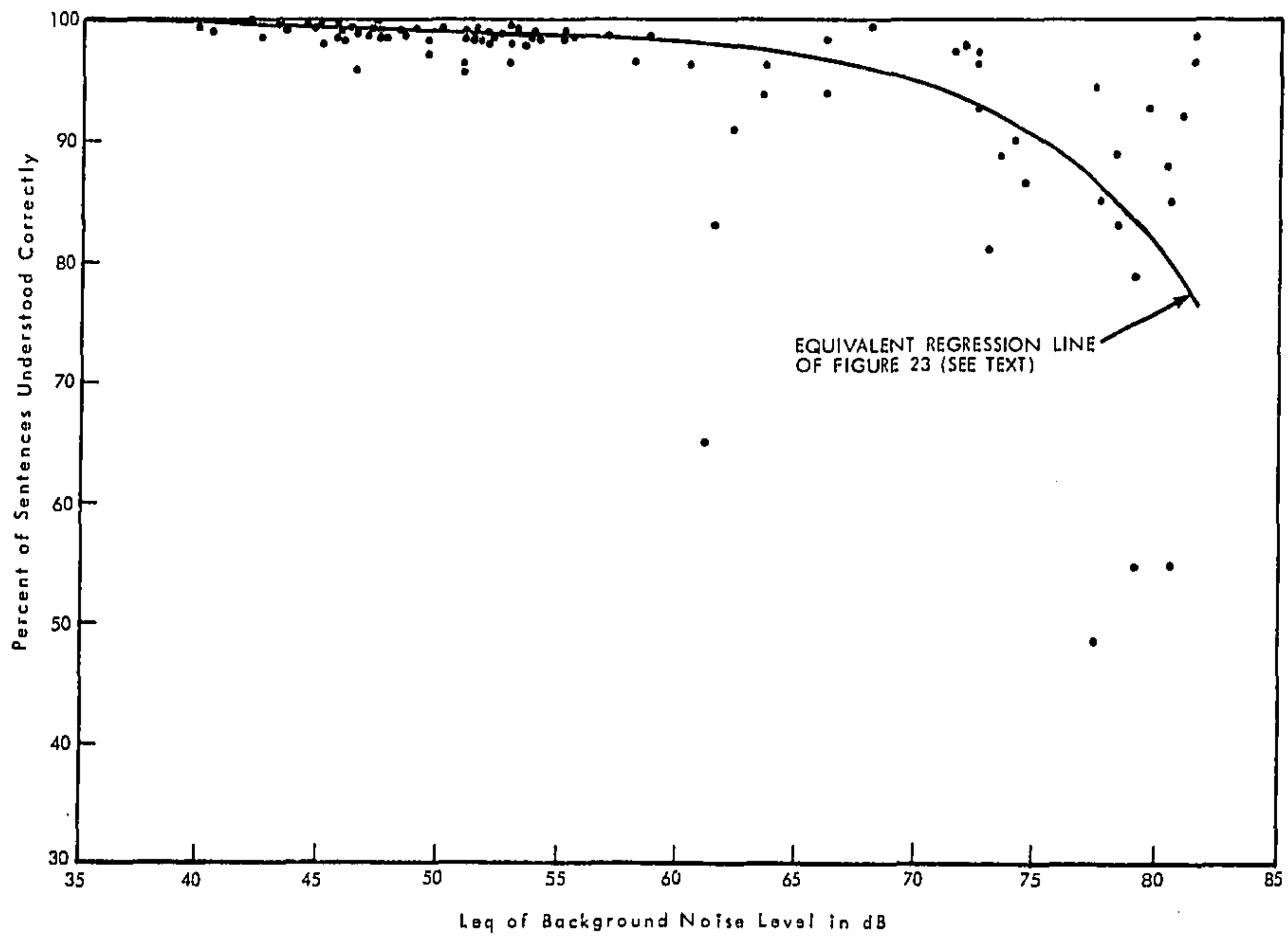

FIGURE 24. SENTENCE INTELLIGIBILITY FOR CONVERSATIONS IN VARIOUS ENVIRONMENTS

(*casual, normal, raised, loud & shout*) ranged from 5 to 12 dB. The smallest increase was between *casual* speech and *normal* speech; the largest increase was between *loud* speech and *shout*.

A comparison of the speech levels in the categories of *casual, normal & raised* for male and female speakers showed approximately a 2 dB difference. These results would not support Beranek's (1954) recommendation that background levels be lowered by 5 dB to accommodate the voice levels used by female speakers. The real effect of vocal effort on speech level is more evident in measurements made for the *loud* and *shout* categories where the difference between male and female speech levels was 5 and 7 dB respectively.

Figure 25 shows the results of this phase of the speech study and compares them with an earlier study by Beranek (1954) in which the criteria for the Speech Interference Level (SIL) were developed. A comparison of the voice range between *normal* and *shout* revealed that in the current study the difference was 28 dB, but in Beranek's results the difference was only 21 dB. Both studies agreed (within 1 dB) on approximately 73 dB for the *loud* speech level. However, for the other speech categories (*normal, raised & shout*) the results from the two studies differed by 3 to 4 dB. The *normal* (57 dB) and *raised* (64 dB) voice levels in this study were lower than those suggested by Beranek with 61 dB and 67 dB respectively; while *shout* was higher by 4 dB.

As Figure 25 indicates the standard deviation between speakers increased with vocal effort from approximately 4 dB for *casual* speaking to 9 dB at the *shouting* level. This increase in

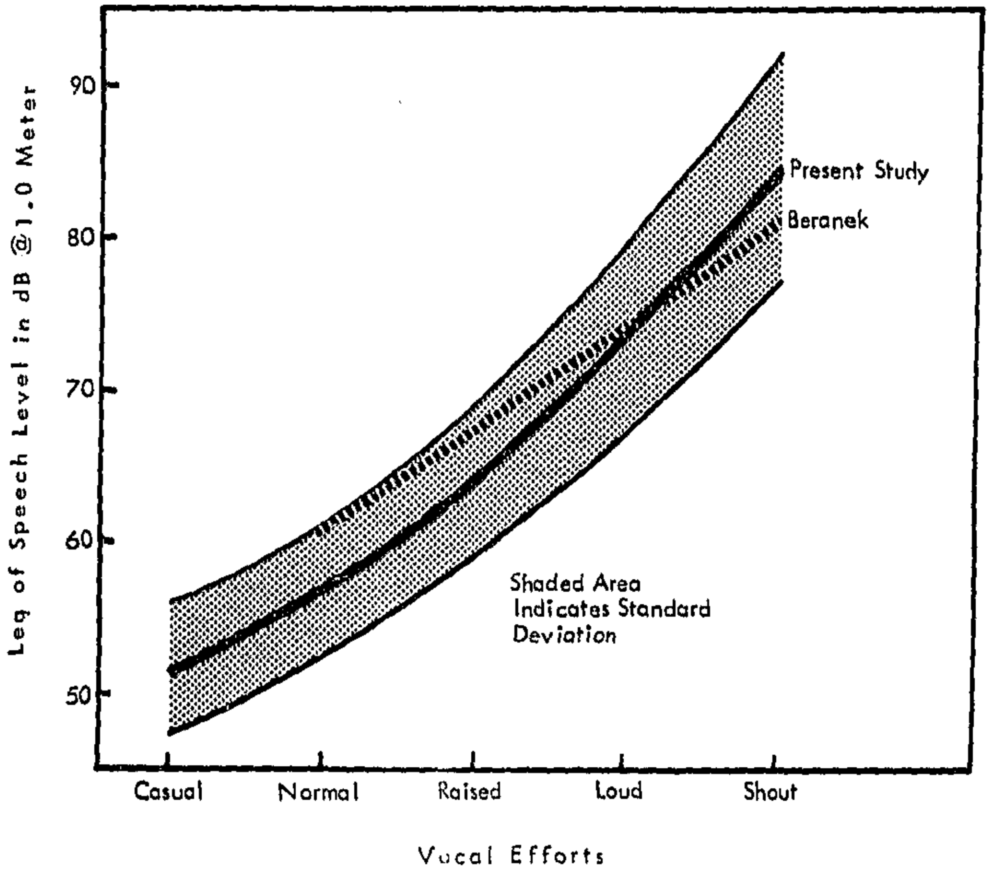

FIGURE 25. SPEECH LEVELS FOR VARIOUS VOCAL EFFORTS

variability between individuals may be attributable to several factors. One explanation is that while all subjects were given the same instructions for measuring their speech in the anechoic chamber, the individuals may have differed in their personal interpretation of the five vocal effort descriptors. For example, it might be more difficult (especially for the children as evidenced by the 9 dB standard deviation) to understand how much vocal effort the experimenter meant when the instructions were to *shout*. The subjects seemed better able to uniformly relate to the instructions to speak in a *normal* voice, with a resulting decrease in intersubject variability. Another factor contributing to the variance between subjects may be related to the difference in individual capabilities to speak at the various voice levels. Thus, most subjects were able to maintain levels within the speech range of the first three speech categories. However, for the vocal effort in the *loud* and *shout* categories, the capacities of the individuals to maintain these levels differed greatly.

Finally, most individuals speak everyday at a speech level which would be characterized as either *casual*, *normal*, or *raised*. Therefore, when asked to speak at a *loud* or *shout* level, they would be less familiar with what level to maintain and they would be far less accustomed to exercising this level of speech.

The shape of the speech spectra also changed in an orderly fashion, providing higher level components at high frequencies for increased voice level. An indication of this trend is the shifting of the maximum one-third octave band from 500 Hz to 1600 Hz (which is approximately 1.6 octaves) as the vocal effort progressed from *normal* to *shout*. The comparison between speech spectra among males, females and children also indicated similarity, except at the higher speech levels. In all cases, however, the speech spectrum presented in the Articulation Index standard (ANSI, 1969), contains less irregularities than in the spectrum obtained for the present data.

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APPENDIX A

INSTRUMENTATION EMPLOYED IN SPEECH MEASUREMENT AND ANALYSIS

INSTRUMENTATION APPENDIX A

Block diagrams are presented in this section of instrumentation used to acquire speech level data, calibrate equipment, and reduce data.

1. Data Acquisition

Equipment used to measure speech levels in classrooms is shown in Figure A-1. Data were recorded on three independent tracks of a standard tape recorder. Figure A-2 shows the typical microphone placement within a classroom.

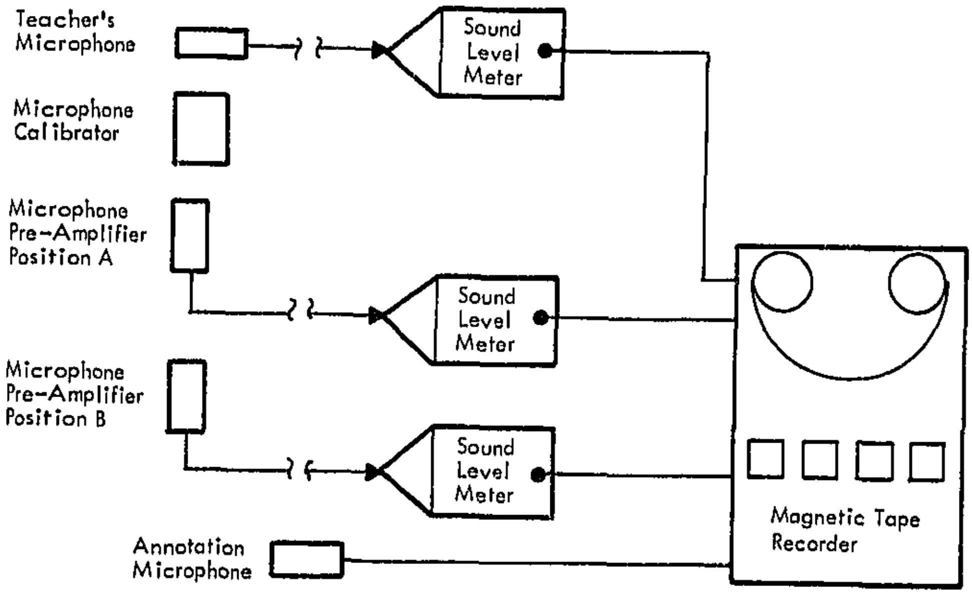
2. Equipment Calibration

Calibration of the teacher's microphone was achieved in an anechoic chamber under conditions outlined in Figure A-3. The basic procedure was to place the miniature microphone immediately adjacent to a standard instrumentation microphone (a 1" B & K condenser microphone). Output levels produced by the two microphones 1 meter from a loudspeaker were then compared at a variety of frequencies and levels. A correction spectrum so developed was incorporated into all subsequent processing involving data recorded by the miniature microphone.

Calibration of the miniature microphone in the field was accomplished via a B & K type 4230 (94 dB) calibrator, for which an adaptor was specially prepared.

3. Data Analysis

All data reduction was accomplished by BBN's real time one-third octave band analysis system, shown in Figure A-4. The process involved playing magnetic tape recordings into a spectrum analyzer, processing the frequency analyzed data digitally, using a specially designed computer program, punching paper tape for long term storage, and listing the paper tapes on a line printer.



A-1 EQUIPMENT FOR MEASURING SPEECH AND BACKGROUND LEVELS IN CLASSROOMS

Teacher's Microphone	Transound, Model 74-A (Minimic)
Microphone	B & K, Condenser, 1.0 Inch
Random Incidence Corrector	B & K, Type UA0055
Pre Amplifier	HP, Type 15108B
Power Supply	HP, Type 15114A
Sound Level Meter	B & K, Type 2205
Magnetic Tape Recorder	Sony, Model 854-4S
Piston Phone Calibrator	B & K, Type 4220
Random Incidence Corrector Adaptor	B & K, Model 152

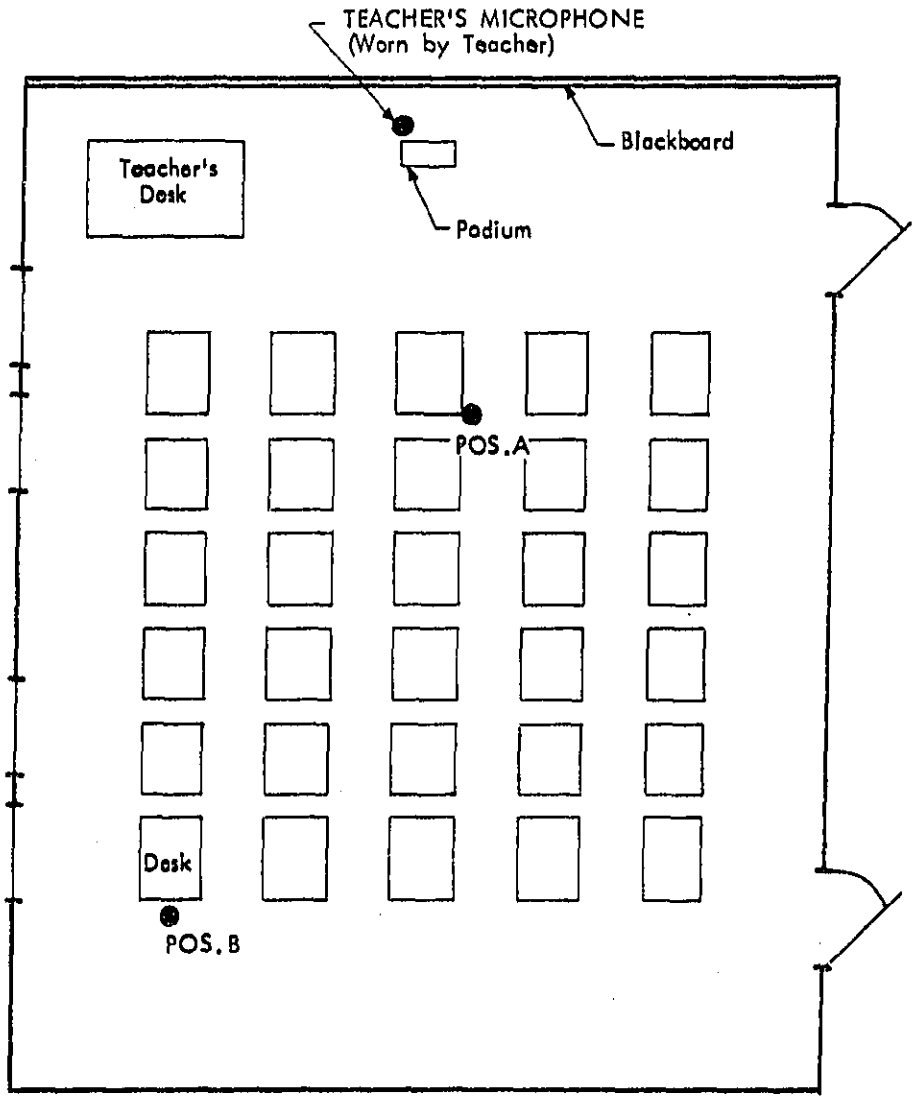
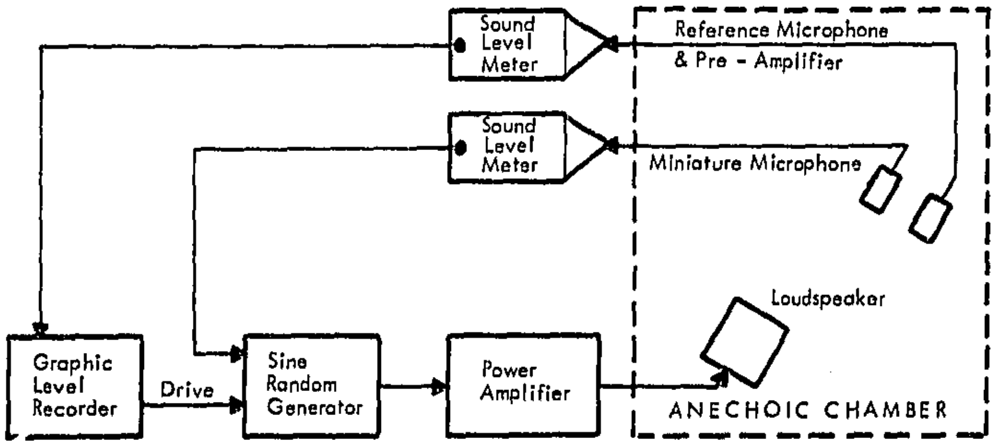
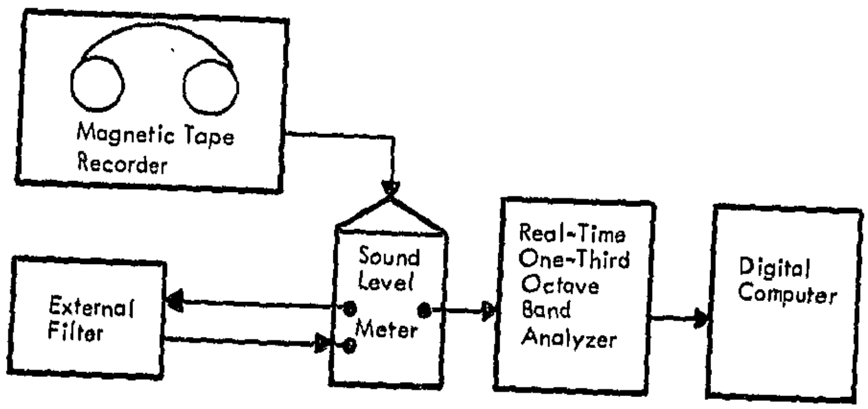


FIGURE A-2. MICROPHONE LOCATIONS IN CLASSROOM



A-3 EQUIPMENT SETUP FOR CALIBRATION OF MINIATURE MICROPHONE USED IN CONVERSATIONAL SPEECH RECORDING

Reference Microphone	B & K, Type 4133, 1/2 Inch
Pre-Amplifier	G-R, Type P42
Sub-Miniature Microphone	Transound, Minimic, Model 74-A or BBN, Electret Microphone
Sound Level Meter (SLM)	B & K, Type 2205
Graphic Level Recorder	B & K, Type 2305
Sine Random Generator	B & K, Type 1024
Power Amplifier	JBL, SE400S
Speaker	JBL, C40
Piston Phone Calibrator	B & K, Type 4220



A-4 SPEECH AND BACKGROUND ANALYSIS SYSTEM

Magnetic Tape Recorder	Sony, Model 854-4S or Nagra, Model SN
Sound Level Meter (SLM)	B & K, Type 2203
External Filter	BBN
Real Time Third Octave Analyzer	HP, Type 8054A

APPENDIX B

INSTRUCTIONS AND WORD LISTS USED IN CLASSROOMS AND ANECHOIC CHAMBER

CLASSROOM INSTRUCTIONS

To the Teacher

Please read the following word list to your students. Read the words one at a time and do not repeat the word even if asked by a student to do so. Read the words at a normal pace and maintain the same classroom lecturing voice level throughout the presentation.

To the Student

Listen carefully to the words the teacher will read. They will be read only once. Do not ask the teacher to repeat a word that you have missed. This is not a spelling test, nor does it count on your grade. Pay close attention and do the best you can.

PHONETICALLY BALANCED WORDS READ IN CLASSROOM

LIST 1	LIST 2	LIST 3	LIST 4	LIST 5	LIST 6	LIST 7
CANE	TANG	WHY	FLOAT	FEED	AS	GASP
THERE	FATE	TURF	SAGE	GAPE	PUN	WOO
DISH	SUCH	GNAW	CLOAK	SICK	ROUGH	THOUGH
HID	ELSE	DROP	RACE	GREEK	NIGH	ACT
HEAP	PIT	JAM	TICK	ROE	BEST	DWARF
PANTS	GILL	FLUSH	TOUCH	CHOOSE	JAG	SCOUT
HUNT	CHARGE	ROUSE	HOT	TRUE	TONGUE	SLEDGE
NO	BOUGHT	NECK	POD	PASS	HITCH	SNIFF
BAR	CLOUD	SOB	FROWN	BROWSE	BOG	FLING
PAN	MUTE	TRIP	RACK	PUNT	ROOMS	COOK
FUSS	BEAN	DILL	BUS	SHOVE	FOWL	DOPE
CREED	SCYTHE	THRASH	BLONDE	HILL	REAP	GUN
BOX	VAST	DIG	PERT	BLACK	WRITE	JUG
STRIFE	RIB	RATE	SHED	HIGH	WIFE	MUD
DIKE	PICK	FAR	KITE	RIND	CLOTHES	PLOD
NOT	HOCK	CHECK	RAW	VASE	GAGE	FAKE
FORD	OUR	AIR	HISS	RODE	FORGE	PHASE
END	HIT	BEAD	FIN	PUFF	PRIME	RASH
THEN	JOB	SPED	SCAB	INCH	SCAN	RICH
BASK	WISH	CAST	HOW	BRONZE	GROPE	BUT
FRAUD	NUT	CLASS	STRAP	SOLVE	SUP	POUNCE
SMILE	DAB	LUSH	SLAP	BATHE	SLOUCH	WHIFF
DEATH	FROG	SHOUT	PINCH	ADD	THUS	PIG
ARE	LOG	BALD	OR	REAR	PRIG	ROAR
BAD	SNUFF	CAPE	STARVE	SHINE	FLICK	SAG
PEST	BLUSH	SIZE	NEW	SLY	BADGE	BY
SLIP	NAB	WEDGE	RUT	WRATH	CLOTH	AM
RUB	BAIT	DECK	NEAT	LOVE	KEPT	NINE
FEAST	BUD	HURL	DODGE	BECK	FLOP	WIRE
DEED	RAP	WHARF	SKETCH	THICK	FALL	AIM
CLEANSE	MOOSE	LEAVE	MERGE	FLAP	WASP	SHAFT
FOLK	TRASH	CRAVE	BATH	CHEAT	ODE	SOUTH
NOOK	GLOSS	VOW	COURT	WINK	HULL	WOE
MANGE	PERK	LAW	OILS	ZONE	FEE	CHOP
SUCH	VAMP	STAG	SHIN	ODDS	LAG	KNIT
USE	START	OAK	PECK	KID	THIGH	RAID
CRASH	EARL	NEST	BEAST	TRADE	CHART	SIN
RIDE	CORPSE	SIT	HEED	SCARE	WAIT	CUT
PILE	SLUDGE	CRIME	EEL	MAST	COB	HIM
RAT	TAN	MUCK	MOVE	PIPE	MASH	DOSE
RAG	WAYS	FAME	EARN	GOOD	EYES	QUIZ
IS	BOUNCE	TAKE	BUDGE	LEND	RAISE	SIEGE
WHEAT	NIECE	WHO	SOUR	YAWN	DEEP	COAST
RISE	AWE	TOIL	RAVE	WATCH	SHANK	GRADE
HIVE	THEM	PATH	BEE	THUD	RAY	FORT
GROVE	NEED	PULSE	BUSH	TUG	GAP	COMES
TOE	QUART	FIG	TEST	CURSE	CRIB	OFF
PLUSH	FIVE	BARB	HATCH	OWLS	PUS	PENT
CLOVE	HIRE	PLEASE	COURSE	NOSE	EAT	RANGE
FERN	SHOE	ACHE	DUPE	GRUDGE	DAD	MOTE

INSTRUCTIONS FOR SPEECH MEASUREMENTS IN ANECHOIC CHAMBER

PLEASE MEMORIZE THE FOLLOWING SENTENCE:

"JOE TOOK FATHER'S SHOE BENCH OUT; SHE WAS WAITING AT MY LAWN."

---

1. Speak in a NORMAL VOICE - that which you would use in everyday conversation.
2. Then speak in a RAISED VOICE.
3. Then speak as LOUDLY AS POSSIBLE without straining your vocal cords.
4. Then speak at a SHOUTING VOICE level.

FOR EACH VOICE LEVEL, REPEAT THE ABOVE SENTENCE UNTIL NOTIFIED TO STOP.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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EPA-600/1-77-025		

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The goal of this study was to determine average speech levels used by people when conversing in different levels of background noise. The non-laboratory environments where speech was recorded were: high school classrooms, homes, hospitals, department stores, trains and commercial aircraft. Results of speech measurements at schools confirmed that teachers in typical classroom situations speak at a consistently higher level (67-78 dB at one meter) than in face-to-face conversation. Further, their vocal effort increased at the rate of 1 dB/dB increase in background noise which ranged from 45 to 55 dB. Speech levels recorded in face-to-face conversation were lower, averaging 55 dB at 1 meter for ambient levels less than 48 dB. As the background level increased above 48 dB to 70 dB, people correspondingly raised their voice levels up to 67 dB at the rate of 0.6 dB/dB as the ambient increased. For background levels less than 45 dB speech levels measured at the listener's ear - disregarding distance between talkers - was also 55 dB. The laboratory study of approximately 100 observers for the four varied speech instructions ("speak in a normal, raised, loud, and shout voice") showed an orderly progression in level, and shift in spectral emphasis as voice levels increased. Comparison of male and female voice levels for the speech categories normal and raised yielded minimal differences. Background levels to achieve speech intelligibility are recommended.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
ambient noise intelligibility acoustic measurement		05 06

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