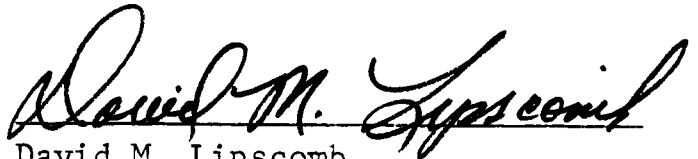


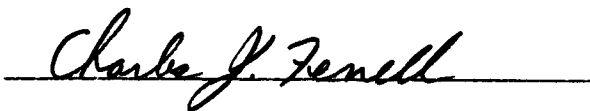
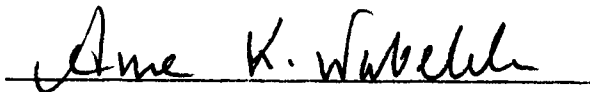
To the Graduate Council:

I am submitting herewith a thesis written by Susan Drake entitled "Speech Discrimination in Noise Through Television Audio Circuitry." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Audiology.



David M. Lipscomb
Major Professor

We have read this thesis and
recommend its acceptance:



Accepted for the Council:



Vice Chancellor
Graduate Studies and Research

Thesis
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SPEECH DISCRIMINATION IN NOISE THROUGH
TELEVISION AUDIO CIRCUITRY

A Thesis
Presented for the
Master of Arts
Degree
The University of Tennessee, Knoxville

Susan Drake
March 1980

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ABSTRACT

The ability to discriminate words in nonsense sentences presented in a +5dB speech-to-noise ratio through two television sound systems with diverse audio quality was compared for subjects with normal hearing and mild sensorineural hearing-impairments.

Analysis of the data revealed no significant difference between discrimination scores obtained through the two sound systems; however, a significant difference between the scores of the two groups of subjects was evident. Further analysis indicated that the hearing-impaired subjects had considerably more difficulty discriminating speech in noise than did the normal hearing subjects.

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CHAPTER I

INTRODUCTION

The intelligibility of television audio signals has thus far received minimal attention, although various other conditions of low fidelity circuitry have been evaluated utilizing speech discrimination tasks. Today some 80 percent of American households include a television set. Survey results indicate that while normal hearing teenagers watch approximately twenty hours per week of television, hearing-impaired and deaf populations are viewing thirty and thirty-plus hours per week, respectively (Sendelbaugh, 1978). With such widespread popularity of this pastime, reports of discrimination difficulties at comfortable listening levels may be frequently encountered clinically.

Most television loudspeakers are three by five inches in size, with a high frequency cut-off at 5000 Hz (Feldman, 1979). The amount of sound energy below 200 Hz is usually negligible. This limits the reproduction fidelity, which Webster (1978) qualified as inverse to the amount of noise and distortion present in the signal. The frequency response, as well as the size and dynamic range of the loudspeaker, will collectively determine fidelity.

Prior to January 1978, television audio and video signals were transmitted separately via American Telephone and

Telegraph wire systems from point of origin or local network affiliates. One disadvantage of this mode was resulting low fidelity sound, with the limited frequency range that is characteristic of telephone system components. Audio and video are now transmitted to local studios along the same cable, enabling transmission of a high fidelity FM signal with a frequency response range from 50 Hz to 15 kHz (Marks, 1978). Before the potential for high-fidelity sound existed, the improvement of television audio systems was not warranted. Currently sound quality in the home is restricted primarily by the limitations of the television receiver.

Some television manufacturers have previously included a tone control for fine tuning adjustments. Recently, sets have become commercially available with separate bass and treble controls, allowing the independent emphasis of low and high frequency regions. Another advancement has been to extend the frequency response range of televisions, including significant amounts of energy from 50 Hz to 10 kHz (Schotts, 1979).

Gerber (1974) indicated that the frequency bandwidth for face to face conversation at a distance of one meter is approximately 80 Hz to 10 kHz. The extent of this range represents the fundamental frequency of low male voices through the uppermost frequencies in voiceless fricatives.

Clearly, the full range of frequencies is not essential to the understanding of conversational speech for normal hearing listeners. This is evidenced by highly intelligible telephone transmissions with limited bandwidths from approximately 300 Hz to 3 kHz. However, due to this restricted bandwidth, telephone communication can be a difficult listening situation for hearing-impaired individuals who may have little or no trouble in face to face conversation. Whether these television-audio developments will also constitute discernible differences to some listeners is yet to be investigated.

Quality comparisons of various television systems have been compiled from consumer ratings to reflect subjective preferences. However, little information is available regarding how well transmissions of television sound systems can be understood in everyday environments by hearing-impaired individuals, as compared to normal hearing persons.

A major difficulty encountered when evaluating the quality of electroacoustical systems is correlating the physically measured "objective" data with the psychological "subjective" dimensions of quality, assuming that a relationship exists. Nakatani and Dukes (1973) refer to speech quality as a conglomeration of attributes, including intelligibility, which determine the suitability of a speech signal for communication. They defined intelligibility as the accuracy with

which a speech sample can be understood by a listener. Intelligibility is influenced by interdependent factors, such as frequency and amplitude distortion of the signal, which also contribute to over-all quality. However, a relative measure of intelligibility can be accomplished, without regard to other quality factors, utilizing speech discrimination testing. Since speech discrimination tests evaluate a listener's ability to correctly repeat speech presented at a level above threshold (Davis and Silverman, 1962), these tests provide a measure of intelligibility for a specific environment, sound system, stimulus, and listener.

Speech discrimination ability is routinely assessed in quiet, acoustically-controlled environments. However, it has been widely suggested that an evaluation under these conditions may not be an accurate index of a subject's ability to understand speech under acoustically natural conditions. Signal distortions, background noise, and prolonged reverberation times are suggested as more appropriate approaches to evaluating day-to-day speech discrimination ability.

A relatively complex listening task is necessary to facilitate a functional-discrimination prognosis for an individual. Less taxing listening environments may not be sensitive enough to discriminate among fine intelligibility differences of sound systems.

Noise is a common communicative disturbance that is easily measured, defined, and reproduced for investigative purposes. In a study of speech discrimination ability in quiet vs. everyday environments, Niemeyer (1967) analyzed the spectra of diverse environmental noises. He reported concentrations of sound energy in the low frequency region, with considerably less energy present at the higher frequencies. Niemeyer indicated that these noises mask low frequency speech information, upon which a patient with a "low-pass filter deafness" (i.e., a high frequency hearing impairment) is dependent for the reception of speech. Kryter et al. (1962) also stated that low frequency-emphasis noises typically occurred in a home environment. Though the presence and level of noise in the home can be regulated to some extent, occasionally less than ideal conditions may exist for a listener.

I. PURPOSE

The purpose of this study was to compare the relative intelligibility of synthetic sentence stimuli presented through two television sound systems having diverse audio quality. A low frequency emphasis background noise was maintained at +5dB speech-to-noise ratio to reflect adverse, but typical, listening conditions. Responses of normal hearing and mild sensorineural hearing-impaired subjects were compared.

II. EXPERIMENTAL QUESTIONS

The following experimental questions were formulated for investigation:

(1) Is there a significant difference between mean discrimination scores obtained in a +5dB speech-to-noise ratio through television-audio circuitry with a relatively limited frequency response range, as compared with scores obtained through television circuitry with extended high and low frequency responses?

(2) Is there a significant difference between mean discrimination scores of the normal hearing and hearing-impaired groups for each listening condition?

CHAPTER II

REVIEW OF LITERATURE

The literature review will focus on the following factors of speech discrimination considered relevant to this study:

- I. Speech Discrimination Tests
- II. Frequency Response of Speech Signals
- III. Detrimental Effects of Noise on Speech Discrimination
- IV. Summary

I. SPEECH DISCRIMINATION TESTS

Tests of speech discrimination ability vary primarily along two parameters--stimulus redundancy and response constraints (Webster, 1978). A variety of materials have been developed and employed for specific purposes in research, from less redundant nonsense syllables to sentence constructions with greater amounts of information. A well documented property of speech perception is the higher intelligibility of longer speech elements, as measured by discrimination tasks. Gerber (1974) stated that sentences are about 15 percent more intelligible than isolated words.

Auditory discrimination is evaluated clinically to quantify an individual's ability to understand speech. Monosyllabic word lists are commonly utilized for this purpose, though their relationship to conversational speech has been questioned. Speaks and Jerger (1965) felt that

such short signals impose limitations in evaluating a subject's capacity to manipulate the changing of speech patterns with time. They considered the processing of temporal parameters crucial to understanding on-going speech. Giolas and Ebstein (1963) compared normal hearing subjects' ability to discriminate monosyllables and continuous discourse samples. They reported that no accurate score prediction for continuous discourse could be made on the basis of scores obtained with monosyllabic stimuli.

Criteria for evaluating "everyday" speech discrimination ability were established by the National Research Council Committee on Hearing and Bio-Acoustics (CHABA), who designated sentence material as appropriate. Sentence lists were developed at The Central Institute for the Deaf (CID) in response to CHABA's criteria that the sentences be representative with regard to vocabulary, sentence length, grammatical structure, and redundancy (Silverman and Hirsh, 1955). Giolas (1966) investigated the relationship of these sentences to a sample of continuous discourse that was shown by phonetic analysis to resemble conversational speech. Error curves calculated for the sentence lists were significantly closer to the curve for continuous discourse than were the curves for monosyllabic lists compared in a previous study (Giolas and Ebstein, 1963).

Kalikow et al. (1977) advocated the use of sentence stimuli for discrimination testing. Sentences with high- and low word-predictability were developed to assess perception of linguistic cues, as compared with the acoustic and phonetic characteristics of speech. Fry (1961) discussed these cognitive variables, emphasizing that speech is only partly a matter of the information received by the peripheral mechanism. Another factor vital to comprehension is the central encoding process.

Materials have been developed by investigators attempting to remove variables of linguistic experience and ability. Synthetic Sentence Identification (SSI) materials were generated by Speaks and Jerger (1965) to incorporate on-going speech characteristics into testing. To minimize a subject's reliance on previous linguistic history, a closed-message set was used. A closed set involves a multiple choice paradigm, i.e., the stimulus is simply identified from among a limited group of written sentences. An open message set presents a more difficult listening task, as the response choices are as infinite as the listener's vocabulary. Rather than identifying a stimulus from among a set of possibilities, the stimulus is repeated by the subject. When tested with SSI materials in quiet, subjects obtained scores of 90-100 percent, regardless of how poorly PB monosyllables were discriminated. The addition of a competing speech message at 0dB

speech-to-noise ratio was necessary to produce a listening task of sufficient difficulty to yield equivalent scores to those for PB-50 lists administered in quiet. Utilizing these sentence lists in more favorable speech-to-noise ratios than 0dB would decrease measurement sensitivity. Any fine differences existing among listening conditions and listeners may not be discernible without an adequately difficult listening task.

Significantly higher scores for closed sets, as compared with open sets, were also noted by Page (1971) for sentence stimuli. Though effects of linguistic history are minimized by the close response set paradigm, decreased task difficulty reduces the sensitivity of the discrimination measure.

Nakatani and Dukes (1973) removed contextual cues of the stimulus by developing nonsense sentences with a grammatical pattern of: "The (adjective) (noun) (past tense verb) the (noun)." Ninety-six monosyllables were chosen from the one thousand most frequently occurring words in the Thorndike-Lorge word count as potential sentence fillers. Words of the appropriate grammatical classification were used to fill each of the four positions per sentence. Sentences were generated by drawing at random, with replacement, one word from each classification to fill the four slots. The four-key-word sets had no words in common. Because word recurrence was controlled only within each sentence, the twenty-sentence lists generated are not homogeneous with

regard to word, and therefore phoneme, frequency of occurrence. Consequently, this lack of homogeneity precludes equal audibility among lists. The relative intelligibility of a word is partially dependent upon its phoneme constitution, with some phonemes more susceptible to masking than others (Kalikow et al., 1977). The content of testing materials needs to be balanced to reflect the frequency of occurrence, or distribution, of speech sounds in the language. Howes (1957) also found a strong positive relationship between the frequency of a word in the language and its correct identification in a discrimination test with an open, or unknown, message set. Some speech sounds can be heard at considerably lower intensity levels than others. Davis (1962) maintained that certain "easy" words can be understood at a level as much as 25dB less than the intensity required for the perception of words with other sound sequence. Davis emphasized that the relative intelligibility of a word list depends upon the way the talker utters the words, as much as upon the influence of "phonemic composition."

II. FREQUENCY RESPONSE OF SPEECH SIGNALS

Investigations have indicated differential effects on the ability to understand filtered speech, as a function of masking noise and the hearing sensitivity of the listener. French and Steinberg (1947) reported that speech discrimination

scores of normal hearing subjects varied with the cut-off frequencies of filtered signals. Discrimination scores were equally deteriorated (66 percent) by a low- or high-pass filtered condition when the cut-off frequency was 1900 Hz. However, for noise-masked speech, Webster (1963) reported that a cut-off frequency between 850 Hz and 1000 Hz divided the signal into equally intelligible regions. His results were consistent with data obtained by Kryter (1962) indicating that noise-masked speech has a filter-crossover or "importance" frequency approximately one octave lower than filtered speech in quiet (French and Steinberg, 1947).

Condon (1975) investigated the effects of frequency filtering on Modified Rhyme Test (MRT) monosyllables for subjects with high frequency sensorineural hearing-impairments. With a cut-off frequency of 1900 Hz, she reported significantly better discrimination scores through the low-pass filter than for the high-pass condition. These results support an hypothesis of Guberina (1964) that the frequency band where hearing-impaired subjects have most hearing sensitivity (i.e., below 1000 Hz) is also the region of frequencies where language is most intelligible to them.

Guberina studied the perception of speech filtered through discrete octave bands of sound energy. He referred to a one-octave band of frequencies as a continuous condition for perception, as there is no interruption of acoustical energy

within that band. Two bands separated by a frequency region with less energy would represent a discontinuous condition, with two discrete reference points for perception. From results of a perceptual study with discontinuous signals, Guberina (1963) concluded that low frequency speech energy (200Hz-400Hz) enhances the perception of high frequency speech information (2400Hz-4800Hz) for normal hearing subjects. These results may also have implications for a hearing-impaired population. By including a band of energy in the low frequencies, where more residual hearing usually exists, it may be possible to enhance the perception of higher frequencies, even though the high frequency components may be below the threshold of reception when presented alone.

III. DETRIMENTAL EFFECTS OF NOISE ON SPEECH DISCRIMINATION

Speech discrimination ability in noise is dependent upon the relative intensities and spectra of the signal and the noise. The effects of noise have been of interest to investigators, presumably since the presence of background noise has become recognized as an integral part of everyday listening conditions.

Kryter et al. (1962) were among the first to demonstrate the importance of high-frequency hearing sensitivity for the perception of speech in noisy, reverberant environments. From correlations of auditory threshold levels with speech

discrimination scores for sentences and monosyllables, they concluded that averaging formulas excluding frequencies above 2000 Hz are not appropriate predictors of the ability to understand everyday speech. Harris (1965) supported their conclusions. He stated that the pure-tone average for 1000 Hz, 2000 Hz, and 3000 Hz may better predict discrimination ability in the presence of background noise than the traditionally averaged frequencies of 500 Hz, 1000 Hz, and 2000 Hz. The correlational techniques applied by Kryter et al. (1962) to a population with predominately high frequency hearing-impairments were criticized by Webster (1964). Because this group included more subjects with hearing-impairments above 2000 Hz than below 2000 Hz, Webster felt their correlations between high frequency thresholds and discrimination scores were artificially high for application to a population with a wider range of impairments. However, Webster agreed that a formula including frequencies above 2000 Hz was "optimal" for individuals with hearing impairments confined to the high frequency region. Frequency averaging techniques recommended by Kryter et al. (1962) were further supported by Suter (1978). The Modified Rhyme Test and CID sentence material were presented in noise to normal hearing subjects and a hearing-impaired group primarily with noise-induced hearing losses. Correlational tests indicated that frequency combinations including frequencies higher than 2000 Hz were

significantly better predictors of everyday discrimination ability than the average of 500 Hz, 1000 Hz, and 2000 Hz.

Other investigators have reported detrimental effects of noise on discrimination capabilities of subjects with sensorineural impairments. Carhart and Tillman (1970) found that hearing-impaired subjects' ability to discriminate monosyllables was more impaired by a competing speech signal than was the performance of normal and conductively-impaired subjects. They stated that the sensorineural group responded as though the competing signal had 12dB to 15 dB more "masking power" than was the case with the other two groups of listeners.

Cooper and Cutts (1971) compared the ability of normal hearing and sensorineural hearing-impaired listeners to understand speech presented in quiet and with recorded cafeteria noise at various speech-to-noise ratios. As the speech-to-noise ratio decreased, greater discrimination score variation was noted within the hearing-impaired group, than was the case with the normal group. Because of the difference in score variability between groups and a larger performance decrement for the hearing-impaired subjects, Cooper and Cutts suggested "that something more than a simple masking effect operates to reduce levels of performance in such an impaired population."

Shapiro et al. (1972) also varied the speech-to-noise ratio with monosyllabic stimuli in discrimination testing to compare scores of normal and sensorineural hearing-impaired subjects. The group with impaired hearing performed significantly poorer than the normal hearing group under all

conditions of noise. The investigators concluded that discrimination ability in noise could not be predicted for hearing-impaired subjects from scores obtained in quiet.

Cohen and Keith (1976) indicated considerable differences in the abilities of normal and hearing-impaired listeners to understand noise-masked speech. They found that as the speech-to-noise ratio became less favorable, scores were increasingly poorer for the impaired group than for the normal hearing subjects. Cohen and Keith advocated the administration of speech tests under various speech-to-noise conditions, concluding that such assessments have greater diagnostic significance than those in quiet.

Similar results for noise-induced hearing-loss subjects were reported by Shipley (1972). Monosyllables were presented at 40db sensation level (RE: Speech Reception Threshold) with several speech-to-noise ratios. The hearing-loss group had consistently more difficulty discriminating speech in noise than did the normal group.

Erber (1971) stated that ambient noise in everyday situations may have a more disrupting effect on the reception of speech by a child with a hearing-impairment than by a normal hearing child. With a low-frequency background noise, word reception for auditory, visual, and audio-visual stimuli was evaluated. As the speech-to-noise ratio was progressively decreased, the normal hearing children maintained maximum auditory discrimination scores to a -10dB

speech-to-noise ratio. Severely hearing-impaired and profoundly deaf groups required speech-to-noise ratios of 0dB and +5db, respectively, to achieve their optimal scores from quiet conditions. Inspection of scores for the more favorable speech-to-noise ratios, suggests increased difficulty in discriminating phonemes with higher frequency components as the level of noise increased. With the addition of visual cues, at the lowest speech-to-noise ratio allowing maximum performance for each group, scores for the normal group improved by 2 percent, while the severely impaired and profoundly deaf groups improved by 37 percent and 57 percent, respectively. Addition of acoustic cues to the visual stimuli improved scores of the deaf group insignificantly. However, these results suggest the importance of combined cues for optimal speech discrimination for a population with some hearing residuum.

Numerous investigators (Carhart and Tillman, 1970; Cooper and Cutts, 1971; Shapiro et al., 1972; Cohen and Keith, 1976; Shipley, 1972; and Erber, 1971) have assessed discrimination ability in various conditions of background noises, presumably due to the role of noise in everyday listening situations. However, the monaural presentations utilized by these studies would seem less representative of everyday listening conditions than a binaural mode in a

sound field. Normal hearing and hearing-impaired individuals have been found to experience a binaural advantage in noise, particularly in reverberant conditions (Moncur and Dirks, 1967; Nabelek and Pickett, 1974). In a pilot investigation, Suter (1978) found a binaural advantage of 13 percent for normal hearing listeners, when the speech-to-noise ratio with Modified Rhyme Test materials was -7dB. Though stating that "binaural listening more closely resembled real life conditions," Suter selected a monaural mode for the subsequent study. She felt that "binaural hearing would influence discrimination scores to an unknown and uncontrollable extent." Nevertheless, to measure functional auditory skills a binaural listening task is suggested, as it would allow subjects to utilize all cues available in day-to-day communication.

IV. SUMMARY

To summarize the literature, the following observations are considered pertinent:

- (1) Speech becomes more intelligible as the length of the speech element increases.
- (2) Connected speech materials yield more representative measure of everyday discrimination ability than do monosyllabic stimuli.

(3) Nonsense sentence stimuli allow intelligibility assessments of sound systems with regard to acoustical factors, by removing variables of the listener's linguistic competence.

(4) Frequency response has been shown to affect the discrimination scores of subjects with sensorineural hearing impairments differently from normal hearing subjects' scores.

(5) Low frequency speech energy enhances the perception of speech information at higher frequencies for normal hearing individuals.

(6) Discrimination scores of sensorineural subjects decline more rapidly in conditions of increasing noise levels than do scores of normal and conductive hearing-impaired subjects.

(7) Discrimination ability of sensorineural hearing-impaired individuals in noise cannot be accurately predicted from scores obtained in quiet.

(8) Hearing-impaired subjects require more favorable speech-to-noise ratios for maximum speech discrimination scores, as compared with normal hearing persons.

(9) A binaural listening advantage in noise has been demonstrated for normal and hearing-impaired subjects.

CHAPTER III

PROCEDURES

In order to answer the experimental questions stated in Chapter I, the following experimental design was formulated:

I. SUBJECTS

Two groups of subjects, a normal hearing group and a hearing-impaired group, were used in the study. Ten native English-speaking adults comprised each group. The following selection criteria were established:

Normal Hearing Control Group (Nc)

(1) Pure-tone air and bone conduction thresholds were no poorer than 25dB (ANSI, 1969), bilaterally.

(2) Speech discrimination in quiet for PB monosyllables was 94 percent to 100 percent, bilaterally.

(3) Young adults between 19 and 28 years of age were selected from an undergraduate class at The University of Tennessee.

Hearing-Impaired Experimental Group (Ne)

(1) The following range for pure-tone air conduction thresholds was delineated to reflect moderately sloping,

mild-to-moderate high frequency impairments:

500 Hz	:	0 dB--30 dB
1000 Hz	:	10 dB--40 dB
2000 Hz	:	15 dB--50 dB
4000 Hz	:	30 dB--60 dB

Mean better-ear hearing levels and ranges for frequencies 250 Hz through 4000 Hz are presented in Figure I.

(2) No greater than 10dB threshold difference between ears at any frequency was required.

(3) Non-hearing aid users were selected.

(4) Adults between 22 and 50 years of age were selected from patient files at The University of Tennessee Hearing and Speech Center.

The hearing aid restriction was specified to avoid the introduction of diverse signal distortions by individual amplification systems. The 50 year old age limit was included because discrimination ability has been noted to decline as a function of increasing age as early as the fifth decade (Broadbent and Heron, 1962; Feldman and Reger, 1967; Mills, 1978). No attempt was made to control for the sex of the subjects, since it has been demonstrated that no difference in discrimination ability exists between male and female listeners (Goetzinger et al., 1961). A written consent form (Appendix A) was obtained from each subject prior to selection testing.

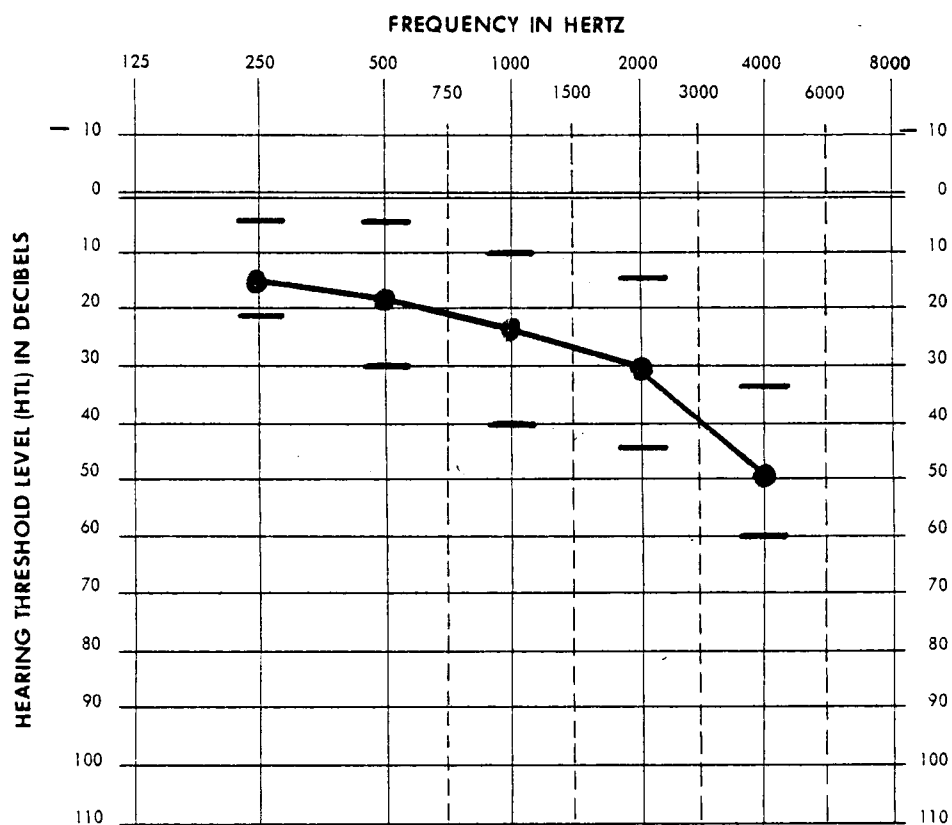


FIGURE 1. MEAN AIR-CONDUCTION THRESHOLDS AND RANGES FOR HEARING-IMPAIRED GROUP

II. EQUIPMENT AND MATERIALS

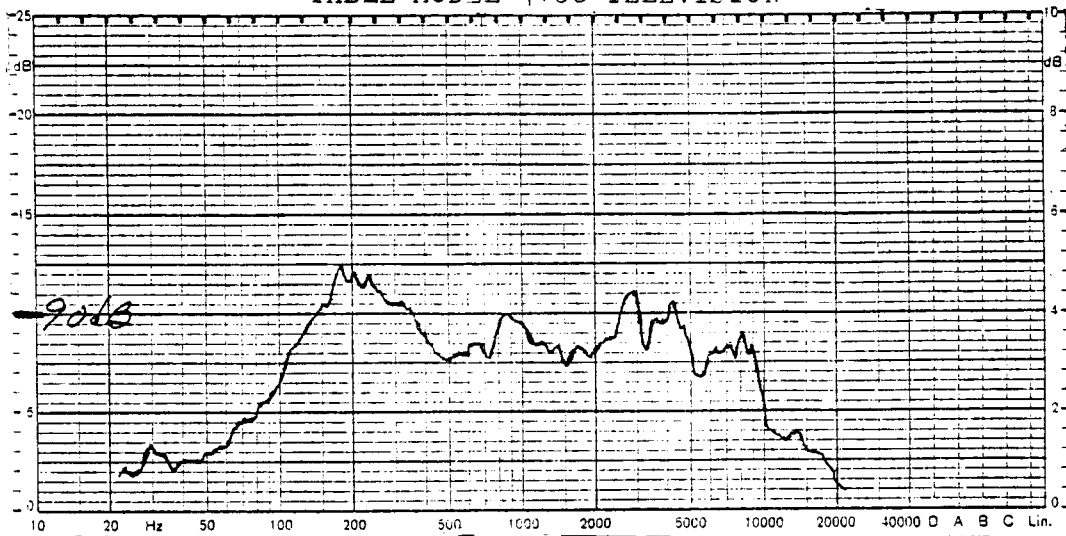
Subject selection procedures were conducted in a two-room hearing testing suite at The University of Tennessee Hearing and Speech Center. A Grason Stadler 1701 audiometer, calibrated for routine clinical use, was utilized.

Speech and background noise stimuli were recorded onto two channels of a magnetic tape for simultaneous presentation. Nonsense sentence material (Nakatani and Dukes, 1973) was employed, each with a grammatical pattern of: The (adjective) (noun) (past tense verb) the (noun). Four initial practice sentences and two lists of twenty sentences each were re-recorded from tapes obtained from Bell Laboratories, using Ampex Model AG445B and AG440B Recorders, in order to juxtapose desired lists. Sentence lists appear in Appendix B.

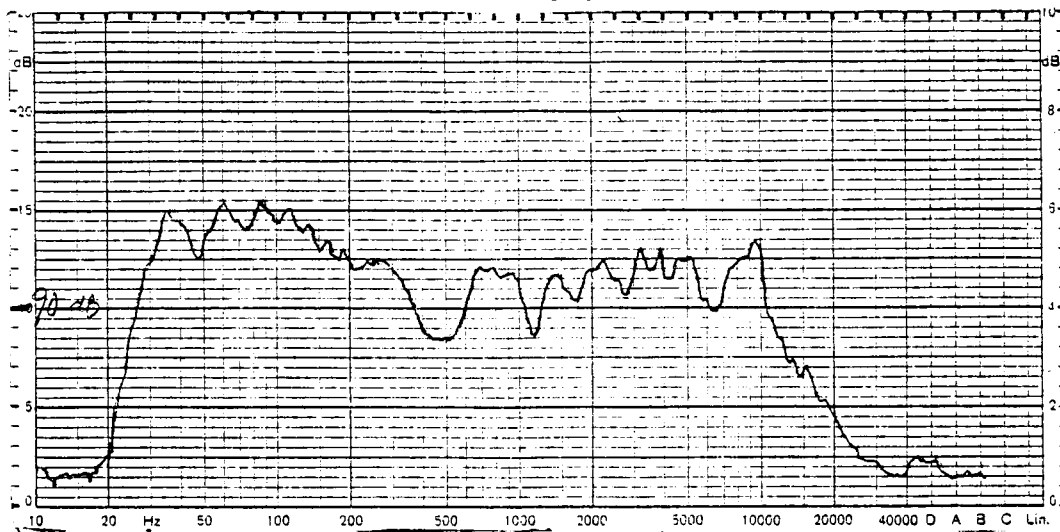
The experimental sound system with a relatively limited frequency response range was a Magnavox table model 4168 television, and the system with an extended frequency range was a Magnavox console model RK5056. Frequency response curves of these systems and the loudspeaker for masking noise presentation were obtained in the experimental environment and are displayed in Figure 2. Dual tone control on console model was adjusted to mid-bass/mid-treble setting. An external audio-input modification on both televisions enabled the presentation of tape recorded material through the sets, utilizing the internal audio-circuitry of each. The

TABLE MODEL 4168 TELEVISION

24



CONSOLE MODEL RK5056 TELEVISION



S45 LOUDSPEAKER FOR MASKING NOISE PRESENTATION

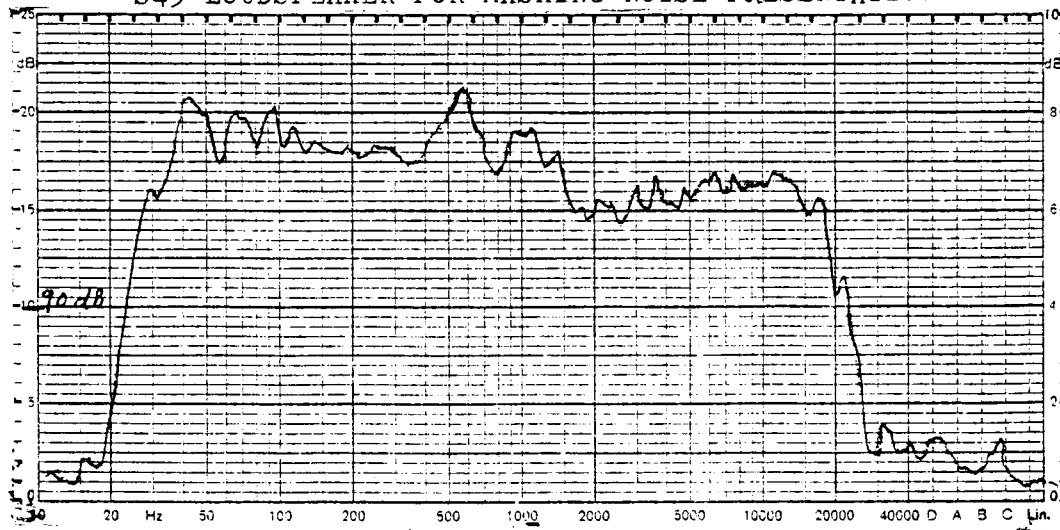


FIGURE II. FREQUENCY RESPONSE CURVES FOR EXPERIMENTAL TELEVISIONS AND MASKING NOISE LOUDSPEAKER

recorded sentences were presented through each system to a Bruel and Kjaer type 4144 one inch condenser microphone and analyzed with a Bruel and Kjaer Type 2307 Level Recorder to determine average sound levels for each list for calibration purposes. The average sentence level was defined as the mean of the six peak levels per sentence. A 0.5dB A-weighted difference between the average level of the two lists was considered insignificant for the purpose of this study.

Masking noise was recorded from an air conditioner with an Ampex Model AG440B Recorder through an Electrovoice RA 20 studio microphone and a Shure microphone mixer. One-third octave band acoustical analysis of the noise, presented through a Bang and Olufsen S45 loudspeaker used for background noise presentation, indicated sound energy concentrations primarily below 1000 Hz. (Figure 3).

Warble tones at octave bands 125 Hz through 8000 Hz were generated by a Bruel and Kjaer Type 1022 Beat Frequency Oscillator and measured with a Bruel and Kjaer Type 2307 Level Recorder to determine reverberation times of the experimental room.

Acoustical calibration of speech and noise presentation systems was accomplished before and after each subject was tested. To calibrate and monitor presentation levels throughout testing a Bruel and Kjaer Type 4144 one inch condenser microphone was positioned adjacent to the subject's head.

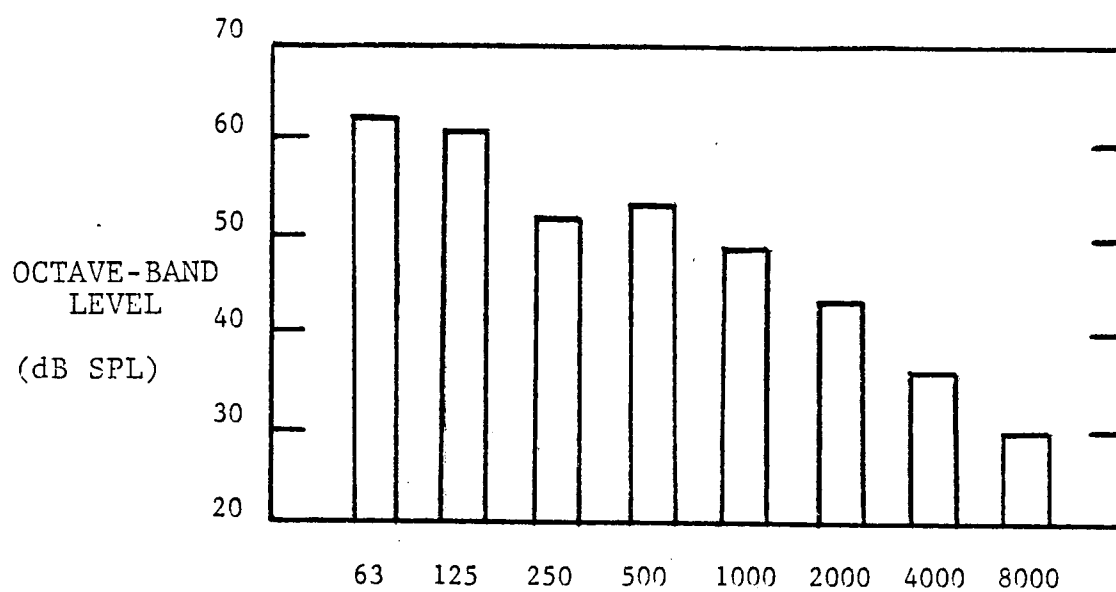


FIGURE III. OCTAVE-BAND SPECTRA OF THE EXPERIMENTAL MASKING NOISE AT A 55 dBA PRESENTATION LEVEL

Microphone Calibration was checked at the beginning and end of each testing day with a Bruel and Kjaer Type 4220 pistonphone and a Bruel and Kjaer Type 2607 measuring amplifier. Pink noise, generated by a Docorder Taperecorder Model 1140, was recorded at the beginning of the tape on both channels for calibration purposes. The amplitude of the pink noise, relative to the mean sentence and noise levels, was determined acoustically with a Bruel and Kjaer Type 2307 Level Recorder through the respective experimental sound systems. The level of the calibration signal, measured in the experimental environment with a Bruel and Kjaer Type 4144 one inch condenser microphone at the subject's position, was adjusted accordingly to yield specified A-weighted stimulus levels for testing.

III. EXPERIMENTAL METHOD

Routine audiometric procedures were administered to obtain pure-tone air and bone conduction thresholds and discrimination scores for PB monosyllables in quiet for all potential subjects. For the ten in each group who met the selection criteria, the following procedures were utilized:

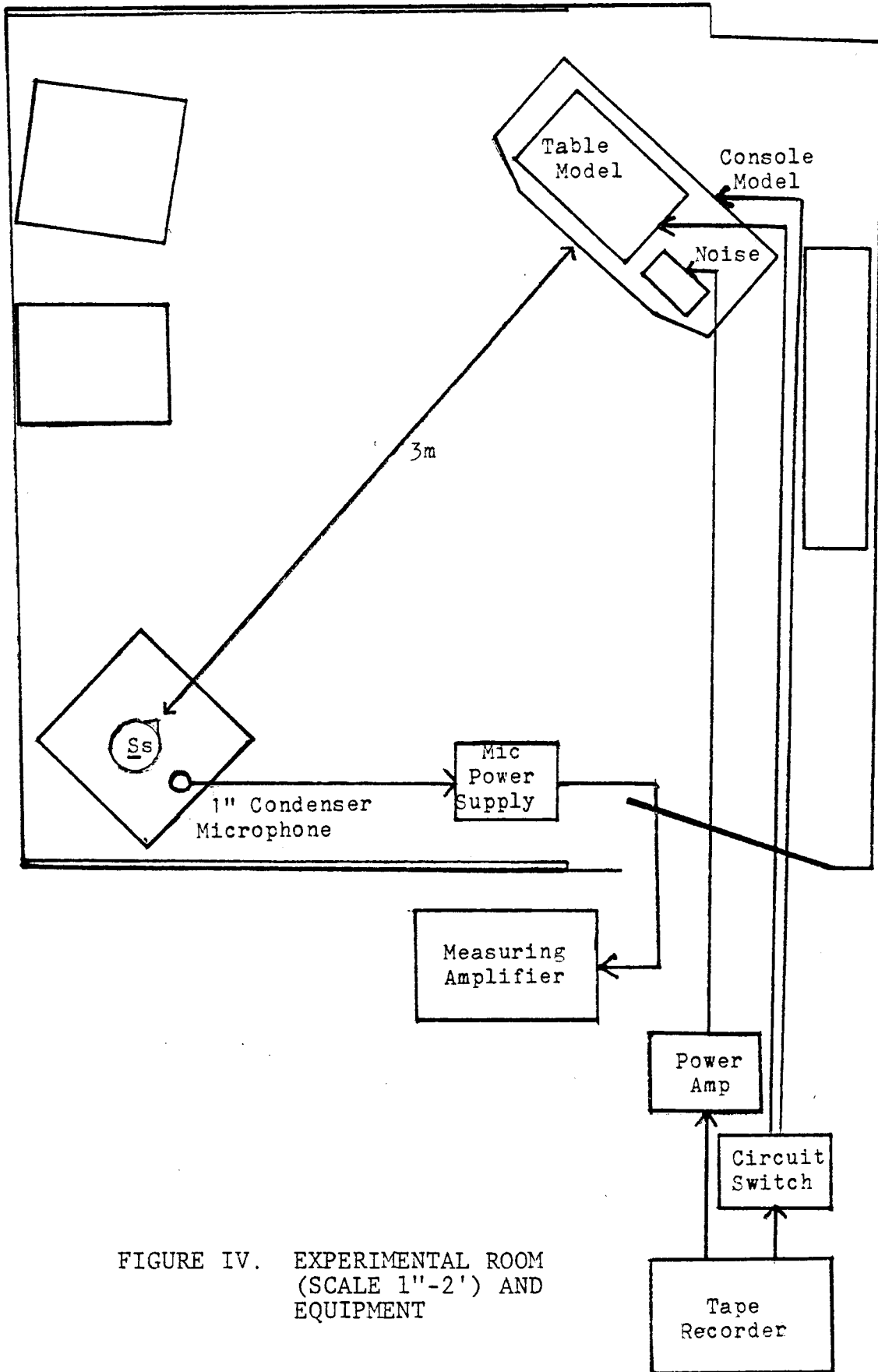
The subject was seated in the experimental room facing the television sets and the background noise loudspeaker at a distance of three meters. The carpeted room (dimensions: 11_L' x 11_W' x 10_H') contained furnishings typical of a home

television viewing environment. A scaled room diagram and the block diagram for experimental instrumentation are presented as Figure 4. A 0.3 sec. reverberation time of the room was calculated as the mean of reverberation times measured for 500 Hz, 1000 Hz, and 2000 Hz. Reverberation times of 0.2 sec., 0.4 sec., and 0.6 sec. have been cited as a range typical for small rooms (Nabelek et al., 1976).

A speech level of 60dBA was used for all subjects and experimental conditions. Suter (1978) referred to this approximate level as representative of a slightly raised conversational level. Since television volume levels may often be adjusted to accommodate a group of listeners under everyday conditions, individuals are forced to listen to speech at various levels, rather than only at a level yielding maximum discrimination performance.

The masking noise was presented at a level of 55dBA to maintain a +5dB speech-to-noise ratio, representing an adverse, though plausible, listening condition. This speech-to-noise ratio may occur with the use of appliances or temperature control units during television viewing. Kryter et al. (1962) indicated that a +5dB speech-to-noise ratio is often present in a home environment.

Written instructions (Appendix C) were provided to each subject and verbally reviewed by the experimenter.



Subjects were encouraged to guess when they were uncertain of a word. Four practice sentences preceded two lists of twenty sentences each, with a 15 second pause between sentences for the subject to write responses on the form provided (Appendix D). The sentences were presented through the two television systems alternately by use of a circuit switch, so that the twenty odd-numbered sentences were heard through the console model and the twenty even-numbered sentences were presented through the table model television set. The alternating presentation mode was employed to compensate for the lack of between-list-homogeneity with regard to audibility, as discussed in Chapter II. Additionally, by presenting half of each list through each sound system, the influence of practice effects, occurring with test experience for the subjects, is balanced between the two listening conditions. Four key words per sentence yielded a total of eighty responses per listening condition, with each response contributing 1.25 percent toward a total possible score of 100 percent.

IV. TREATMENT OF DATA

The above procedures were repeated, utilizing List 1, on two subjects from each group immediately following all experimental testing in order to assess re-test reliability. Discrimination scores for each subject were recorded for

the two experimental listening conditions. These data were subjected to a two-way analysis of variance (Bruning and Kintz, 1977) to evaluate the interaction of hearing sensitivity and listening conditions. T-tests for related measures (Bruning and Kintz, 1977) were applied to mean discrimination scores obtained for List 1 and List 2 in both experimental listening conditions. This measure was employed in order to evaluate homogeneity of sentence lists (See Discussion section).

CHAPTER IV

RESULTS AND DISCUSSION

The data analyzed in the present study were obtained from two groups with ten subjects (Ss.) each. The control group (Nc) had normal hearing and the experimental group (Ne) had mild sensorineural hearing-impairments that sloped moderately toward the high frequencies. Speech discrimination scores obtained for each S were calculated as percentage measurements of correctly recorded words. The main experimental question was: Is there a significant difference between mean discrimination scores obtained in a +5dB speech-to-noise ratio through television audio-circuitry with a relatively limited frequency response range, as compared with scores obtained through television circuitry with extended high and low frequency responses?

Results obtained from a computation of the data will be discussed as follows: (1) reliability of measurement; (2) over-all means and ranges; (3) statistical analysis and; (4) discussion.

I. RELIABILITY OF MEASUREMENT

Two randomly chosen Ss from each group were retested with List 1 immediately following the experimental conditions. A Pearson Product-Moment Correlation Coefficient was calculated

to evaluate re-test reliability (Bruning and Kintz, 1977). A correlation coefficient of 0.98 ($N = 4$), significant beyond the 0.2 level, indicated that the procedure was reliable.

II. OVER-ALL MEANS AND RANGES

The mean score for Nc was 84 percent for the limited frequency response condition, with scores ranging from 75 percent to 89 percent. For the extended frequency response condition, Nc mean score was 87 percent, with a score range from 81 percent to 93 percent. The mean scores for Ne were 62 percent for the limited condition with a range of scores from 30 percent to 86 percent, and 66 percent for the extended condition, with scores ranging from 39 percent to 85 percent. Raw scores, means, and ranges are presented in Table I.

III. STATISTICAL ANALYSIS

Speech discrimination scores for Nc and Ne in both listening conditions were subjected to a two-way analysis of variance (Bruning and Kintz, 1977). This analysis is summarized in Table II.

Scores obtained in the two listening conditions did not differ significantly for the two groups of Ss ($F = 0.97$, $df = 1/36$, $p > .2$). Thus, in response to the first experimental question, there was no significant difference

TABLE I

RAW DISCRIMINATION SCORES IN TWO LISTENING CONDITIONS

HEARING-IMPAIRED GROUP (N _e)			NORMAL HEARING GROUP (N _c)		
<u>Ss</u> #	LIMITED CONDITION (%)	EXTENDED CONDITION (%)	<u>Ss</u> #	LIMITED CONDITION (%)	EXTENDED CONDITION (%)
1	45	39	11	84	88
2	61	73	12	86	93
3	86	85	13	81	91
4	75	69	14	81	89
5	73	80	15	85	83
6	75	85	16	89	89
7	30	46	17	89	91
8	65	74	18	88	81
9	56	60	19	85	85
10	49	50	20	75	83
MEAN	61.5	66.1	MEAN	84.3	87.3
RANGE	30-86	39-85	RANGE	75-89	81-93
VARI- ATION	56%	46%	VARI- ATION	14%	12%

TABLE II

SUMMARY OF ANALYSIS OF VARIANCE FOR EVALUATION
OF MEAN SCORE DIFFERENCES BETWEEN TWO
LISTENING CONDITIONS AND BETWEEN
TWO GROUPS OF SUBJECTS

SOURCE OF VARIANCE	SUM OF SQUARES	df	MEAN SQUARE	F	p
TOTAL	10330.4	39	---	---	---
HEARING CLASS	4340	1	4340	32.63	< .001
LISTENING CONDITION	144.4	1	144.4	0.97	> .2 (n.s.)
HEARING CONDITION	6.4	1	6.4	0.04	> .2 (n.s.)
ERROR	5339.8	36	148.33	---	---

between mean discrimination scores obtained in a +5dB speech-to-noise ratio through television-audio circuitry with a relatively limited frequency range, as compared with scores obtained through television circuitry with extended high and low frequency responses.

When mean scores for both listening conditions are compared for the two groups, there was a significant difference between over-all performance of Nc and Ne ($F = 32.63$, $df = 1/36$, $p < .001$). In order to ascertain which listening conditions produced mean discrimination scores that were significantly different between the two groups of subjects, t-tests for independent measures were applied (Bruning and Kintz, 1977). A mean score difference of 21 percent between Nc and Ne in the extended frequency response condition was significant beyond the .001 level of confidence ($t = 3.94$, $df = 18$, $p < .001$). In the limited frequency response condition, the 22 percent mean score difference between groups was significant beyond the .001 level ($t = 4.14$, $df = 18$, $p < .001$). Therefore in answer to the second experimental question, there was a significant difference between mean discrimination scores of the normal hearing and hearing-impaired groups for each listening condition.

IV. DISCUSSION

Results of the analysis of variance indicated no significant difference between mean discrimination scores achieved in the two listening conditions for either group of Ss. Direct observation of scores obtained in both listening conditions indicated higher scores for List 2, as compared with List 1, for 18 of the 20 Ss. A series of t-tests for related measures (Bruning and Kintz, 1977) were applied to assess inter-list differences for both experimental listening conditions. Results from analysis of the data are summarized in Table III. Significant differences between mean discrimination scores obtained with List 1 and List 2 were indicated for both groups of Ss under both listening conditions. Mean speech discrimination scores were significantly lower for List 1 than List 2, and the inter-list differences were greater in the limited frequency response condition, as compared with the extended condition. This trend was apparent for both groups of Ss, though more pronounced for the hearing-impaired group than the normals by a factor of two. These results indicate that the differences between sentence lists affected the ability of the hearing-impaired group to discriminate speech more so than the ability of the normal hearing group.

Analysis of mean sentence levels (Chapter III: Equipment and Materials) indicated a 0.5dBA difference between List 1

TABLE III

SUMMARY OF t-TESTS FOR RELATED MEASURES
ASSESSING BETWEEN-LIST-HOMOGENEITY

		MEAN SCORE % LIST 1	MEAN SCORE % LIST 2	DIFFER- ENCE %	df	t	p
NORMAL HEARING GROUP (N _c)	LIMITED CONDI- TION	79.1	89.6	10.5	9	4.36	<.001
	EXTENDED CONDI- TION	84.1	90.4	6.3	9	3.87	<.01
HEARING- IMPAIRED GROUP (N _e)	LIMITED CONDI- TION	51.6	71.3	20.2	9	7.43	<.001
	EXTENDED CONDI- TION	59.1	73.3	14.2	9	4.96	<.001

and List 2. However, because the higher mean intensity level calculated was for List 1, which evidenced lower scores, the mean-score-differences between sentence lists are not considered a function of mean-sentence level differences.

The significant difference in the ability of Ss to discriminate the two lists of sentence material suggests a lack of between-list-homogeneity with respect to intelligibility. This inter-list difference may be attributed to the word-intelligibility factor of phonemic composition, as discussed by Kalikow et al. (1977) and Davis (1962). Both studies indicated the necessity of balancing the content of speech discrimination testing materials to represent the distribution of sounds in the language, as some phonemes are more susceptible to masking than others.

Analysis of the data indicated a statistically significant difference between mean discrimination scores of the two groups of Ss. However, due to the fixed levels of speech and noise presented in this study, the sensation level (RE: SRT) of the stimuli varied among Ss, as a function of individual speech reception thresholds. The mean sensation level received by the normal hearing listeners was 60dB; and with an average speech reception threshold of 15dB for the hearing-impaired group, the mean sensation level of the speech was 45dB. Thus, direct comparison of these results, with those of investigations utilizing the same sensation

level for each S, is not appropriate. Nevertheless, the assessment of discrimination ability in this study, under conditions resembling adverse, though plausible "everyday" environments, differentiated normal hearing and hearing-impaired Ss, similarly to results with other investigative designs.

For S selection testing, discrimination scores with monosyllabic stimuli were obtained in quiet utilizing an average sensation level of 40dB for all Ss. Better-ear scores ranged from 94 percent to 100 percent for the hearing-impaired Ss and were 100 percent for all normal hearing Ss. Comparison between scores for monosyllables in quiet and scores for nonsense sentences in a +5dB speech-to-noise ratio, indicates a greater decrease in discrimination scores for the hearing-impaired Ss under conditions of noise, than was evident for the normal hearing listeners. Mean scores for monosyllables in quiet and nonsense sentences under two conditions of +5dB speech-to-noise ratio, are represented in Figure 5. While the scores for monosyllables in quiet did not differentiate between these two groups of listeners, the presence of masking noise deteriorated the scores of the hearing-impaired Ss more so than those of the normal Ss.

Further inspection of individual scores under the experimental conditions (Table I) indicates a greater range

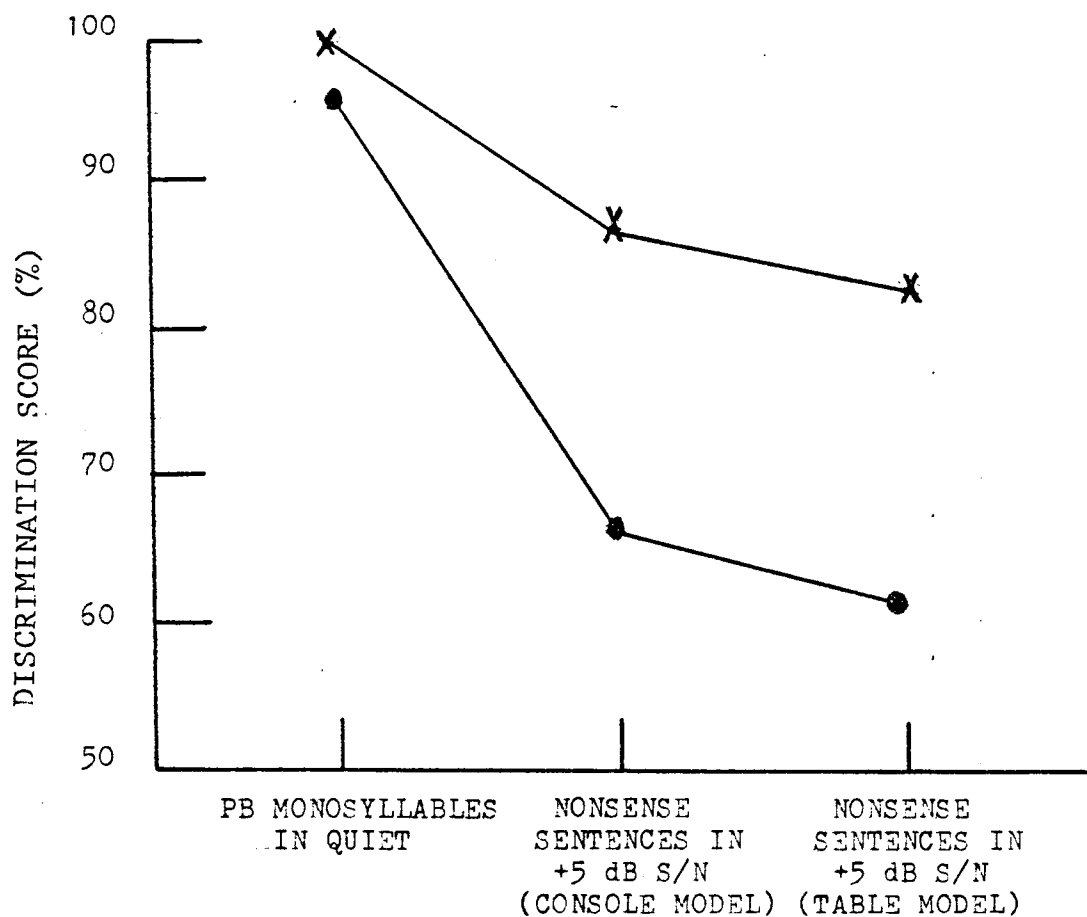


FIGURE V. COMPARISON OF MEAN SCORES OBTAINED IN QUIET WITH MEAN SCORES OBTAINED IN NOISE

NORMAL GROUP: X
HEARING-IMPAIRED GROUP: ●

of scores within the hearing-impaired group than within the normal group. The above results are consistent with trends noted by Cooper and Cutts (1971). Presenting speech in quiet and noise they found a larger performance decrement and greater score variability within a hearing-impaired group, than within a normal group, as the speech-to-noise ratio decreased. The findings of this study are in agreement with other investigators (Carhart and Tillman, 1970; Shapiro, 1972; Cohen and Keith, 1976; and Shipley, 1972) who reported that sensorineural hearing-impaired Ss' ability to discriminate speech was more impaired by background noise than was the performance of normal hearing Ss. In addition, the conclusion of Shapiro et al (1972), that discrimination ability in noise could not be predicted for hearing-impaired listeners from scores obtained in quiet, was supported by the results of the present investigation.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

It was the purpose of this study to compare the relative intelligibility of speech presented in noise through two television sound systems with diverse audio quality. Performance of normal hearing and mild sensorineural hearing-impaired Ss was compared.

Two groups of ten Ss each participated in the study. Young adults between the ages of 19 and 28 years comprised the normal hearing control group (Ne) and adults between 22 and 50 years with mild bilaterally symmetrical sensorineural hearing-impairments were selected for a hearing-impaired experimental group (Ne).

Two experimental questions were formulated for investigation pertaining to (1) the difference in speech discrimination scores obtained in noise through two experimental sound systems, and (2) the difference between discrimination scores of the normal and hearing-impaired Ss.

The results are summarized as follows:

(1) The procedure utilized in this study was found to be reliable in regard to test-retest accuracy.

(2) There was no significant difference between mean discrimination scores obtained in noise through the two experimental television audio systems.

(3) There was a significant difference ($p < .001$) between mean discrimination scores of the normal hearing and hearing-impaired groups under both listening conditions.

II. CONCLUSIONS

The following conclusions were indicated by the results of this study:

(1) The experimental procedure is a reliable measure.

(2) The two lists of synthetic sentence material presented in this study were not homogenous, with regard to intelligibility.

(3) Inter-list differences evidenced greater mean score differences for the hearing impaired Ss, than for the normal hearing Ss, by a factor of two.

(4) No significant differences were observed between the ability of either group of Ss to discriminate speech in a +5dB speech-to-noise ratio through a television sound system with a relatively limited frequency response range, as compared with scores obtained through television circuitry with extended high and low frequency responses.

(5) Mild sensorineural hearing-impaired Ss have considerably more difficulty discriminating speech in noise than do normal hearing Ss.

(6) Discrimination ability of sensorineural hearing-impaired individuals in noise cannot be predicted accurately from scores obtained in quiet.

(7) Greater score variation was evident within the hearing-impaired group than within the normal group.

III. LIMITATIONS OF THE STUDY

The factors presenting limitations to the present study are as follows:

(1) Utilizing a single speech-to-noise ratio precludes comparison of discrimination ability in progressively more adverse conditions of noise.

(2) The fixed speech level, selected to represent everyday conditions, will not allow maximum discrimination ability for all Ss, thus limiting comparisons between Ss and limiting information regarding optimal ability to understand speech.

(3) The lack of homogeneity between sentence lists employed influences total discrimination scores obtained for statistical analysis.

(4) The present procedure is limited in relating to previous research due to variations in testing materials and listening conditions used in past research.

(5) Generalizations from these results to a population are limited by the sample size of ten Ss per group.

(6) By removing linguistic history variables through use of nonsense stimuli, conclusions regarding functional discrimination ability of an individual are limited.

IV. IMPLICATIONS FOR FURTHER STUDY

The following topics are suggested for further research:

- (1) A replication of this study, comparing speech discrimination scores in quiet to those obtained in several speech-to-noise ratios with identical testing stimuli.
- (2) Assessments of discrimination ability at a most comfortable level (MCL) for each S.
- (3) Replicating this study utilizing "everyday" sentence material, as CID sentence lists which were designed to represent colloquial speech.
- (4) Compare speech discrimination ability through diverse television sound systems for hearing-impaired Ss wearing individually fitted hearing aids. Such a design would yield information regarding the optimal discrimination performance possible for each Ss.
- (5) Replication of this study utilizing an amplifier with differentially adjustable frequency band filters, as employed by the Verbo-Tonal System, for the comparison of discrimination ability in discontinuous frequency response conditions. As with hearing aid circuitry, a broad, flat frequency response may not facilitate optimal discrimination ability for all audiometric configurations.

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APPENDICES

APPENDIX A

WRITTEN INFORMED CONSENT DOCUMENT

You are asked to participate in a study to assess the intelligibility of television broadcasts in the presence of background noise. You will participate in one experimental session, approximately one hour in length, to include:

1. A brief hearing test.
2. Listening to forty recorded sentences and responding by writing each sentence as accurately as possible.

I understand and agree to the following:

1. Individual identities will be kept confidential, as will all data obtained.
2. All test results will be available to me upon request.
3. The background noise levels will not exceed those typical of a home television-listening environment.
4. Tests will be conducted by qualified individuals.
5. I am free to withdraw consent and discontinue participation in the study at any time.
6. Refusal to participate will not effect any future contacts you may have with the University of Tennessee Hearing and Speech Center.
7. This project has been approved by the University of Tennessee Committee on Research Participation and potential subjects are not at risk.
8. Any further questions concerning these procedures will be answered. For additional information, please contact:

David M. Lipscomb, Ph.D.
Phone: 974-4123 (office)
573-9013 (home)

Signature _____

Date _____

APPENDIX B
SYNTHETIC SENTENCES

List 1

THE FULL	CUP	SAW	THE SEA
THE HIGH	CLUB	NAMED	THE WALK
THE SOFT	HAT	HURT	THE BILL
THE FINE	RED	NAMED	THE LIFE
THE GRAY	GUARD	FILLED	THE SEA
THE TENTH	HALL	FORMED	THE HOUR
THE PLAIN	DEATH	CAUGHT	THE WAR
THE GLASS	CHAIN	NAMED	THE WALL
THE FIRST	CROWD	SENT	THE STREAM
THE SIDE	DRIVE	PRESSED	THE WORD
THE OLD	EDGE	FIT	THE TREE
THE LARGE	SONG	HELD	THE DAY
THE PLAIN	ROSE	WATCHED	THE JUDGE
THE FREE	FOOT	MADE	THE SKIN
THE ILL	TIRE	BEAT	THE HOPE
THE SMALL	CUP	ROCKED	THE SCHOOL
THE DEAD	TEAR	HELPED	THE WIND
THE CLEAN	SKY	RUSHED	THE GIRL
THE LATE	RIDE	LOVED	THE END
THE CLEAN	NEWS	DARED	THE SHIP

SYNTHETIC SENTENCES

List 2

THE FINE	PAGE	RUSHED	THE EYE
THE BIG	STICK	BROUGHT	THE DOOR
THE BIG	MEN	FILLED	THE PLAY
THE STRANGE	CROWD	SPREAD	THE LIFE
THE DARK	BRIDGE	ROCKED	THE PART
THE LEAST	FLOOR	KISSED	THE NIGHT
THE FIRST	GROUND	HURT	THE END
THE PLAIN	CHURCH	SET	THE BILL
THE STRANGE	HALL	PICKED	THE FACT
THE SOFT	LIP	GAVE	THE WIND
THE MEAN	PIECE	WORKED	THE HOME
THE TENTH	DOUBT	MISSED	THE COURT
THE LAST	SKY	SAW	THE RACE
THE RIGHT	FLY	PAID	THE KING
THE BRIGHT	HALL	USED	THE BILL
THE SAME	LIP	SAILED	THE FIGHT
THE STRANGE	BOAT	MARCHED	THE FACT
THE REAL	HEAT	CAUGHT	THE WORD
THE WEST	BOAT	CALLED	THE WORD
THE GLAD	FLOOR	TOLD	THE CAR

APPENDIX C
INSTRUCTIONS TO SUBJECTS
LOUDSPEAKER INTELLIGIBILITY TEST

INSTRUCTIONS:

The purpose of this experiment is to test various loudspeaker systems, rather than your ability to understand speech. No one is expected to understand all the words, so do not be frustrated when you find some difficult to hear.

You will hear some nonsense sentences in a background of noise. Try to ignore the noise and concentrate on listening to the voice. After each sentence is spoken, write what you think you heard on the answer sheet. If you are not sure of some of the words, please guess.

First you will hear four practice sentences. Write these on the answer sheet on the practice lines A-D. These will be more difficult to understand than the actual test words to help you become accustomed to listening in a noisy situation.

It is important that you face straight ahead when listening to the sentences; however, you are free to move your head to write.

Remember that these sentences will not make sense and to guess when you are not sure of the words.

APPENDIX D
RESPONSE FORMS

SUBJECT # _____

Practice (A-D)

A. THE	_____	_____	_____	THE	_____
B. THE	_____	_____	_____	THE	_____
C. THE	_____	_____	_____	THE	_____
D. THE	_____	_____	_____	THE	_____

Test (1-40)

1. THE	_____	_____	_____	THE	_____
2. THE	_____	_____	_____	THE	_____
3. THE	_____	_____	_____	THE	_____
4. THE	_____	_____	_____	THE	_____
5. THE	_____	_____	_____	THE	_____
6. THE	_____	_____	_____	THE	_____
7. THE	_____	_____	_____	THE	_____
8. THE	_____	_____	_____	THE	_____
9. THE	_____	_____	_____	THE	_____
10. THE	_____	_____	_____	THE	_____
11. THE	_____	_____	_____	THE	_____
12. THE	_____	_____	_____	THE	_____
13. THE	_____	_____	_____	THE	_____
14. THE	_____	_____	_____	THE	_____
15. THE	_____	_____	_____	THE	_____
16. THE	_____	_____	_____	THE	_____
17. THE	_____	_____	_____	THE	_____
18. THE	_____	_____	_____	THE	_____
19. THE	_____	_____	_____	THE	_____
20. THE	_____	_____	_____	THE	_____

21.	THE	_____	_____	_____	THE	_____
22.	THE	_____	_____	_____	THE	_____
23.	THE	_____	_____	_____	THE	_____
24.	THE	_____	_____	_____	THE	_____
25.	THE	_____	_____	_____	THE	_____
26.	THE	_____	_____	_____	THE	_____
27.	THE	_____	_____	_____	THE	_____
28.	THE	_____	_____	_____	THE	_____
29.	THE	_____	_____	_____	THE	_____
30.	THE	_____	_____	_____	THE	_____
31.	THE	_____	_____	_____	THE	_____
32.	THE	_____	_____	_____	THE	_____
33.	THE	_____	_____	_____	THE	_____
34.	THE	_____	_____	_____	THE	_____
35.	THE	_____	_____	_____	THE	_____
36.	THE	_____	_____	_____	THE	_____
37.	THE	_____	_____	_____	THE	_____
38.	THE	_____	_____	_____	THE	_____
39.	THE	_____	_____	_____	THE	_____
40.	THE	_____	_____	_____	THE	_____

VITA

Susan Drake was born in Orlando, Florida in 1955. She moved to Columbia, Tennessee in 1969, where she graduated from high school in 1973. She entered The University of Tennessee as a freshman in 1973 and received a Bachelor of Arts in Speech Pathology in 1977. The Spring of 1978 she entered graduate school at The University of Tennessee and was awarded a research assistantship with The University of Tennessee Noise Research Laboratory the following year. She received a Master of Arts in Audiology in March 1980.