A STUDY OF VOWEL INTENSITY AS RELATED TO THE LOMBARD EFFECT

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Carolyn Jean Livingstone

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A STUDY OF VOWEL INTENSITY AS RELATED TO THE LOMBARD EFFECT

By

Carolyn Jean Livingstone

An Abstract

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ABSTRACT

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TO THE LOMBARD EFFECT

by Carolyn Jean Livingstone

The purpose of this research study was to determine the relationship between the Lombard effect and vowel intensity with respect to specific questions. The questions proposed were: (1) How intense is the voice reflex for each isolated vowel sound when specific levels of white noise (masking) are presented to the right and left ears? (2) How intense is the voice reflex for each isolated vowel sound when specific levels of white noise (masking) are presented binaurally? (3) Is there a significant difference in the intensity of the voice reflex on vowel sounds between the binaural and monaural masking? (4) Is there a systematic intensity pattern that characterizes the eleven spoken vowel sounds?

Twelve, normal hearing, graduate students in Speech and Hearing Science, Michigan State University were used as subjects in the experiment. Equipment used consisted of: (1) an audiometer, (Allison Model 20); (2) headsets, (Telephonics TDH--39); (3) microphone, (Electro-voice 654); (4) tape recorder, (Ampex Model 601); (5) tape, (Scotch Tenzar Backing Magnetic Tape 311); and (7) a modified electric

timer, (GraLab Mocrotimer). The twelve subjects produced a series of eleven randomized vowels at which time white noise was fed into their ears. binaurally, right and left at 70, 80, 90, and 100 db (re: 0.0002 microbar).

The findings indicate the mean intensity of utterances corresponding to the four intensitiies of white noise differ significantly in binaural and monaural (right) presentation. There appears to be no significant difference in mean intensities in monaural (left) presentation. With all three modes of presentation there is a significant difference in the mean intensities of utterances corresponding to the eleven vowels and there is significant interaction between vowels and intensity of white noise. The mean intensity for the three different modes of presentation differ significantly from one another. All vowel sounds demonstrated a greater mean intensity when the white noise presentation was binaural.

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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF ILLUSTRATIONS

Figure | Page

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The research reported in this thesis has as its purpose to determine the relationship between the Lombard effect and vowel intensity with respect to specific questions.

The presentation of material includes first; the statement of the problem which includes a hypothesis, a definition of terms and specific questions to be answered about the Lombard effect as it is related to vowel intensity. This is followed by the justification of the thesis topic through a review of pertinent literature in the area of vowel intensity studies and Lombard effect studies. The procedures for the study are reported; including (1) the test facilities, equipment, and materials, (2) the description of subjects, and (3) the procedures used in conducting the experiment. A statistical anlaysis of data collected and an interpretation of the data constitute the results of the research project. The significance of the data is discussed in the summary and conclusions.

It is hoped the results of this research study may contribute information which will stimulate further studies of (1) the Lombard effect, (2) vowel intensity, and (3) communication in noise.

Hypothesis

It was noted some years ago that a speaker with normal hearing will unconsciously adjust the level of his own voice to maintain it over the surrounding noise level. This phenomenon is known as the "voice reflex" or the "Lombard effect" and was the basis for the development of the Lombard Voice Reflex Test for the detection of malingering in the testing of hearing.

This phenomenon, the Lombard effect, has been incorporated in the Lombard Test and in addition has stimulated research in the area of (1) tests for malingering and (2) communication in noise. The pertinent literature has been reviewed and will be presented in Chapter II of this thesis.

The literature examined by the writer motivated proposal of the questions to be answered within this research study.

In the research involving the Lombard effect the studies have dealt primarily with (1) intelligibility, (2) duration, (3) rate, (4) frequency, and (5) intensity with words and continuous speech in noise or communication in noise. This study proposes to place emphasis on the measurement of vowel intensity as related to the Lombard effect. The intensity of the vowel sound in isolation will be measured in contrast to numerous studies in which vowel intensity has been measured with consonantal influence present. The specific vowel sounds to be used for measurement of intensity are eleven American vowels.

This particular study proposes to answer the following questions:

1. How intense is the voice reflex for each isolated vowel sound when specific levels of white noise (masking) are presented monaurally?
2. How intense is the voice reflex for each isolated vowel sound when specific levels of white noise (masking) are presented binaurally?
3. Is there a significant difference in the intensity of the voice reflex on vowel sounds between the binaural and monaural masking?
4. Is there a systematic intensity pattern that characterizes the eleven spoken vowel sounds?

These four questions define the problems to be considered in the present research study.

Distinctiveness of the Study

It is evident from the review of literature presented in Chapter II that there have been numerous experimental studies concerned with the measurement of vowel intensity as well as studies utilizing the voice reflex or Lombard effect. In all the vowel intensity studies reviewed, the emphasis has been the vowel in a consonant setting and therefore consonantal influence has been present. In the research involving the Lombard effect the studies have not been limited to intensity of an isolated sound but have dealt in terms of duration, rate, frequency, and intensity with words and continuous speech in noise or communication in noise. The distinctiveness then of this research project is:

1. the measurement of isolated vowel intensity without consonantal influence and in an environment of noise, and
2. a study of the Lombard effect measuring the intensity of isolated vowel sounds.

The results of this experimental study may contribute significant information in the area of (1) measurement of vowel intensities, (2) the Lombard effect, and (3) communication in noise.

Definition of Terms

It is desirable at this point to specifically define the terms Lombard effect and the Lombard Voice Reflex Test. Newby states:

> This test is based on the fact that we monitor our own voices through the sensation of hearing. If we are speaking in a noisy environment, we unconsciously increase the intensity of our voice to compensate for the masking effect of the noise.[1]

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[1] Hayes A. Newby, Audiology Principles and Practice (New York: Appleton-Century-Crofts, Inc., 1958), pp. 156-157.

Korn defines as "psychological feedback" the same phenomenon.

> It is evident that every person will tend to adjust the level of his own voice to maintain it over the ambient noise level.[1]

Taylor says:

> That one unwittingly increases the loudness of his voice when he is unable to hear it because of deafness or because of the masking effect of the environmental noise is the principle on which this test is based.[2]

These definitions present the basis on which the Lombard Voice Reflex Test was developed.

Grove relates effectively the causes of the simulation of deafness or malingering that create the need for audiometric evaluation procedures such as the Lombard Test. When the simulation of deafness is a conscious act it is usually an attempt to defraud. However, the simulation of deafness may also be an unconscious act at which time it is indicative of an abnormal state of mind. The otologist is responsible for detecting malingering whether it is conscious or unconscious. Conscious simulation or malingering is found most frequently in times of economic stress and war. It may be used to avoid military responsibilities or "to extract a pecuniary award to which the perpetrator is not entitled."[3] The feigning of

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[1]T. S. Korn, "Effect of Psychological Feedback on Conversational Noise Reduction in Rooms," Journal Accoustical Society of America, XXVI (September, 1954), 793.

[2]Glenn J. Taylor, "An Experimental Study of Tests for the Detection of Auditory Malingering," Journal of Speech and Hearing Disorders, XIV (March, 1949), 119,130.

[3]W. E. Grove, "Simulation of Deafness," Annals of

deafness may be unilateral or bilateral and it may be either partial or complete. Bilateral simulation is fortunately more uncommon as it is very difficult to detect because the patient has prepared himself to be on guard constantly.

Grove continues with a description of the process of administering the Lombard Voice Reflex Test.

> A Barany noise apparatus is alternately sounded in the patients "bad" and good ears so that he becomes acquainted with its characteristics and will not be easily startled thereby.

The patient is given material to read and instructed to read orally and to continue no matter what happens. The noise is introduced to the good ear while the patient is reading. In the case of a patient whose alternate ear is deaf he will "automatically raise the intensity of his voice or even shout as he continues to read."[1] However, the malinger maintains an even tone or in some cases a slightly raised tone will occur.[2] The basic assumption here is that the malinger is capable of monitoring the loudness of his voice with his unmasked "bad" ear.

Otology, Rhinology, and Laryngology, LII (September, 1943), 573-580.

[1] Ibid.

[2] Ibid.

Newby gives a different description of the Lombard Voice Reflex Test and places a different significance on the results. The process of evaluation in the Lombard Test is based on the patient reading material while masking is presented into earphones which he wears. The increases and decreases in the patients voice are noted by the tester as the level of the masking noise is fluctuated.

> The result of the test is positive if the patients voice does become more intense when the masking is increased.

The tester notes at what level of masking the patient's voice becomes more intense and this is compared with the degree of hearing loss the patient is supposed to have. When the patient's voice is affected by the level of masking being less than the particular degree of the supposed hearing loss, it is an indication that the patient is really hearing at lower levels than those to which he has admitted.

> The result of the Lombard Test is negative if the patient's voice remains at the same intensity regardless of the fluctuations in the level of the masking noise within the limits of the supposed hearing loss.

The Lombard Test is used predominantly in determining bilateral functional loss, however, it can be used monaurally. This is accomplished by presenting a constant masking noise in the good ear as a variable noise is placed in the ear that is supposed to be impaired.[1]

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[1] Newby, loc. cit.

Heller, *et al*., resolve the conflict in this manner.

> While the patient reads aloud, masking is first introduced into the "deaf" ear. If there is an increase in voice volume, we give credence to the thought that the ear does hear. Even if the voice does not change, we then mask the better ear. If there is an increase in the voice volume, we suspect that the "deafened" ear is impaired. If there is no change in the voice volume when the good ear is masked, we suspect that the alledgedly deafened ear is permitting the patient to monitor his own speech volume.[1]

Despite the variation in interpretation and method of administration of the Lombard Voice Reflex Test the basis for the test, as previously defined still remains the same.

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[1]Morris F. Heller, M. Anderman, and Ellis E. Singer, *Functional Otology: The Practice of Audiology* (New York: Springer Publishing Co., Inc., 1955), p. 90.

CHAPTER II

REVIEW OF LITERATURE

Due to the nature of this research study, literature related to vowel intensity studies will first be reviewed followed by the presentation of the Lombard effect studies.

Vowel Intensity Studies

Vowel intensity has been the subject of previous research studies, but not in terms of measurement in an environment of noise.

In 1926, Sacia and Beck published the results of a study in which 16 subjects produced eleven monosyllabic words. The words used were: team, tool, took, tone, talk, top, tap, ten, tape, tip, ton. The initial consonant [t] remained constant but there were five different final consonants. In the analysis, sounds were considered individually on the basis of instantaneous and mean power and were represented in terms of microwatts. The vowel sounds in particular were compared with regard to conversation and normal values. There was also a comparison of peak and mean values.[1]

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[1] C. F. Sacia, and C. J. Beck, "The Power of Fundamental Speech Sounds," Bell System Technical Journal, V (July, 1926) 393-403.

Black, in 1949, reports the results of a research project which sought to determine intensity, duration, and frequency from the same sample of vowels and investigate possible interrelationships among the three characteristics by the use of analysis of variance. In the experiment forty-two males read eleven words into a microphone: [tip], [tɪp], [tep], [tɛp], [tæp], [tap], [tɔp], [tʌp], [top], [tʊp], [tup]. The subjects each (1) practice the words under direction, (2) produced the words while in a standing position in a sound treated room; the distance between the lips and the microphone was standardized at 10 inches, and (3) read the words at five-second intervals. There were four sets of measurements made; one each for intensity and frequency and two for duration. They were obtained in the following manner.

> (1)The peak vertical displacement of the graphic recorder stylus was used as an indication of the peak intensity of the vowel in the word. (2) The duration of the vowel was also calculated from the record. . . The length or horizontal dimension of the tracing of the deflected stylus was assumed to indicate the duration of the word. . . (3) The magnetic properties of tape recordings were utilized in determining the frequency of the vowels. Each sound was spotted on the tape, and the portion of the tape that contained the word was immersed in iron filings. The filings arranged themselves in striations, crosswise of the tape, sufficiently plainly to be counted. The speed of the tape through the recording head was determined. The total striations (sound waves) in the vowel could be counted and the distance they occupied on the tape measured. Frequency was computed from these measures. (4) The length of magnetized portion of the tape was measured for another determination of duration.

No quantitative conclusions were made with regard to the interrelationships among frequency, duration, and intensity. However, independent analysis of variance demonstrated significant differences among some vowels in their natural frequency, duration and intensity. It was determined that frequency of the vowel varied with the degree of openness of the vowel. Also, duration varied directly with the openness of the vowel. In addition, significant differences were found among the over-all intensities of vowels.[1]

In an experimental study of vowel intensities, Fairbanks, House, and Stevens were concerned with two specific questions:

> Are there significant differences between the intensities of vowels that may be attributed to the vowels as such? Does a given vowel vary significantly in intensity in relation to its consonantal environment?

The subjects usedby the researchers were 10 young adult male college students. The materials used were 110 words, 10 for each of the eleven vowels. The vowels were: [i], [I], [e], [ɛ], [æ], [ʌ], [ɑ], [ɔ], [o], [ʊ], [u]. All the words were meaningful consonant-vowel-consonant monosyllables. Eight different voiceless consonants were

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[1]John W. Black, "Natural Frequency, Duration, and Intensity of Vowels in Reading," Journal of Speech and Hearing Disorder, XIV (September, 1949), 216-221.

used. Each of the subjects spoke 110 words while positioned 10 inches from a microphone. The recording apparatus was arranged conventionally in two rooms and recording was direct. The graphic record of a word demonstrated a peak-like curve with a readily identifiable maximum. A single value was obtained for each word. (The level of the maximum in db above a common arbitrary reference.)

The results of the statistical analysis of the collected data indicated (1) that most of the common American vowels, when spoken in isolated words, are significantly different in mean intensity and (2) when the same vowel is spoken in different isolated words its intensity may vary significantly in part due to consonantal environment. According to the researchers the differences in mean intensities and their relationship to physiological differences between the vowels merits further investigation.[1]

Steven and House outline a contemporary acoustical theory of vowel production in a 1961 research publication. The relative intensities of vowels are considered to a limited extent. The authors report that it has long been recognized that different vowels "generated" with the same

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[1]G. Fairbanks, A. S. House, and L. Steven, "An Experimental Study of Vowel Intensities," Journal Acoustical Society of America, XXII (July, 1950), 457-459.

vocal effort have different over-all levels. The range of over-all levels for the common vowels of American English is approximately 4 to 5 db, with[i],and[u],having the lowest levels and[æ], [ɑ], and[ɔ] the highest levels.[1]

Lombard Effect Studies

Taylor studied the effectiveness of certain principles on which numerous tests of malingering have been based. In addition, the study was designed to evaluate if results of the tests could be reported in objective terms that would adequately describe the qualitative and quantitative aspects of a supposed unilateral loss. The Lombard Test was used as one of the tests because it has appeared throughout the literature and has been used extensively. The subjects used in the experiment were 32 normal hearing persons, 13 hard-of-hearing persons, and 12 normal hearing graduate students in speech correction. The author requested that the sophisticated group of speech therapists "attempt to beat the test." Taylor concluded that the Lombard Test was useful for the detection of malingering in unsophisticated subjects, but was invalidated by trained subjects. Also it was determined that it is not possible with the Lombard Test to make qualitative or quantitative evaluations of hearing in a supposed deaf ear.[2]

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[1]Kenneth N. Stevens and Arthur S. House, "An Acoustical Theory of Vowel Production and Some of its Implications," Journal of Speech and Hearing Research, IV (December, 1961), 303-320.

[2]Taylor, loc. cit.

Communication in noise is a problem which in the past has been most prevalent in war time. Several pertinent research studies follow which have as their purpose effective communication in noise.

In 1946, a series of articles which were the result of war-time research related to speech training were published in Speech Monographs with John W. Black as editor of the particular series. In 1943, the army requested that investigations be undertaken for the purpose of providing a training program for increasing the effectiveness of interphone and radio communication concerned with aircraft. The aim of the training program was functional. That is, it had as its purpose to improve voice efficiency in order to get messages through to a listener. This aspect of speech was studied under the limiting circumstances of high level noise, such as that characteristic of the interior of military airplanes, and with the voice in rise over army intercommunication and radio sets. The majority of this work was done at the Voice Communication Laboratory, Waco Army Field, Texas. Service personnel were used as experimental subjects. The work continued for two years, until mid 1945. One of the most pertinent sections of the series entitled "Intelligibility Related to Loudness" indicated that for operating both aircraft radios and interphones, loudness of voice is an important factor and the voice should be loud--just under shouting.[1]

Hanley and Steer conducted a research study in 1949, which was designed to measure the effects of masking upon (1) speaking rate, (2) mean syllable duration, and (3) mean speech intensity level. Forty-eight students were directed to read a seventy-three-word passage into a microphone while airplane type noise was fed into the headsets at predetermined levels. In measuring mean intensity level the tape was used in a High Speed Power Level Recorder. The tape was divided into 5 db line markers. Those peak values were summed, then divided by the number of peaks to give a mean peak value for each reading for each subject. The following conclusions were made. Subjects who have not been trained to communicate in noise are confronted with a communication problem in the presence of noise. They appear to react in what has been termed a desirable manner. That is "subjects reduce rate of speaking, prolong syllables, and speak with greater intensity as noise increases." It is interesting to note in the results that there is a stronger response given to an increase in a noise barrier at lower levels. The reverse occurs in the upper levels. The "response" becomes

[1]John W. Black (ed.),"Studies in Speech Intelligibility," <u>Speech Monographs</u>, XIII (Number 2, 1946), 1-64.

less intense as the subject's limits of response potentialities are approached.[1]

Korn studied the effect of room-conversation-type noise upon the vocal output of those speaking in competition with it. The author presented white noise to the speaking-listening environment of 50 subjects. The noise level was increased in steps of 10 db, from 40 db to 90 db, and then decreased in the same manner.

> It was demonstrated that low noise levels (below 45 db or so) do not seriously influence speech power. For higher noise levels, however, over 55 db, the slope of <u>k</u> of the speech-versus-noise curve becomes steeper and can be estimated as constant and equal to about 0.38 db/db.

That is to say, that with the increase of one decibel in the room noise there was an increase of 0.38 decibels in the speech level. This occurred at levels above 55 decibels.[2]

Dreher and O'Neill hypothesized that possibly speech produced in noisy surroundings might include compensatory factors, which within a certain range might be more intelligible for a listener under poor reception conditions to understand.

> . . . therefore, the plan of the study was to get the reaction of several speakers under several

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[1]T. D. Hanley and M. Steer, "Effect of Level of Distracting Noise upon Speaking Rate, Duration, and Intensity," <u>Journal of Speech and Hearing Disorders</u>, XIV (December, 1949), 363-368.

[2]Korn, <u>loc. cit</u>.

> levels of masking at the ear, comparing intelligibility of the speech so produced against a constant background of masking noise with a large number of listeners.

The authors tested the hypothesis in the following manner. Fifteen subjects were employed to read five sets of spondee words and five air traffic control sentences. This was first done with dead phones and then with 70, 80, 90 and 100 decibels of white noise fed into their headsets. Later an overlay of wideband random noise was recorded on the test tapes, at 4 decibels lower than the peak values of the speech signals. These recordings were then played to a listener panel and intelligibility scores were computed for words and sentences. It was determined through analysis that the level of 70 decibels allowed for 35 per cent better word intelligibility scores and 27 per cent better sentence intelligibility scores than the recordings done at the "quiet" level. It was found that there was not an increase in intelligibility at 80 and 100 decibels (90 db was not available due to an error in administration).

> Although intensity of the voice did not contribute to the intelligibility results, the original recordings could be measured to estimate the effect of speaker-masking on his production. . .The largest intensity increase comes, both for words and sentences, when the first level of masking is employed. After that, succeeding increments of 10 db masking produced an average vocal increase of approximately 1 db.

The conclusions of Dreher's and O'Neill's research study of speaker intelligibility in noise are as follows:

(1) There is a measurable and important increase in the intelligibility of both words and sentences produced by speakers operating with a broadband random noise mask in their headsets. (2) The intelligibility values of speech produced under 70 db of masking were statistically equivalent to those produced under 80 and 100 db of masking. (3) Plots of both mean duration of speech elements and vocal output show a regular increase with increase in speaker masking. (4) The range of masking between "Quiet" and 70 db of masking needs further exploration to determine additional points on both the intelligibility and vocal output curves, and it is suggested that live voice tests for hearing evaluation consider the use of sufficient speaker masking to effect the vocal stability observed in this study. (5) It is recommended that the observation of increased intelligibility be put to operational test in aircraft circuits. (6) It is recommended that the aforementioned test, if successful, should result in the engineering of a device for emergency use in air-ground communications for speakers in relatively quiet speaking environments.[1]

The most recent study, to the author's knowledge, on the Lombard effect was done by Waldron in 1960. The purpose of the study was to obtain the answers to seven questions. These questions are as follows:

(1) Will the unsuspecting naive subject demonstrate a voice reflex when one of his two normal ears is masked? (2) Will the sophisticated examinee be able to control his voice reflex when stimulated monaurally? (3) Is there a marked difference between the extent of voice reflex resulting from monaural noise presentation and that resulting from binaural presentation? (4) Can the sophisticated subject control his voice reflex when noise is introduced into both ears simultaneously? (5) Will gradual or instantaneous presentation of the masking noise result in the greater voice reflex for naive subjects? (6) Which one of the

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[1]John J. Dreher and John J. O'Neill, "Effect of Ambient Noise on Speaker Intelligibility of Words and Phrases," Laryngoscope, LXVIII, Part I (1958), 539-548.

two modes of presentation will bring about a greater reflex by the sophisticated test subjects? (7) Will any of the test conditions yield a significant oral reading rate change?

In order to answer these specific questions equipment was used which:

1. gradually introduced a complex masking noise into one or both ears,
2. allowed by-passing the gradual introduction mechanism so that noise could be presented instantaneously,
3. provided a pick-up microphone for the reader's voice,
4. traced the relative voice intensity levels, and
5. allowed measurement of the words-per-minute reading rate for each subject.

There were four groups of twenty subjects each. Group I knew nothing about the test and had the noise presented gradually. Group II were informed of the principles of the test and requested to attempt to "beat it," by controlling the tendency to change reading rate or vocal intensity. Group I also received a gradual presentation. Group III had the masking noise presented instantaneously and did not know of the purpose of the test. Group IV, as Group II, were told to "beat the test" and received the noise instantaneously. The intensity changes and words-per-minute rates were recorded under both monaural and binaural masking conditions.

The results of the research study were as follows:

1. Monaural stimulation elicited statistically significant changes in vocal intensity for all groups.
2. The sophisticated subject groups recorded vocal reflex scores which were significantly smaller than those of the uniformed groups under the binaural presentations; the monaural stimulation scores of the uninformed and sophisticated groups did not differ significantly.
3. The binaural stimulation resulted in a significantly greater voice reflex than the monaural stimulation, for all groups.
4. The rate of presentation of the masking noise did not seem to have any affect on the extent or control of the voice reflex.
5. None of the test conditions resulted in significant changes in the oral reading rates of the subjects.[1]

Summary

It is evident from the review of literature that there have been numberous studies conducted on the measurement

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[1]D. L. Waldron, "The Lombard Voice Reflex Test: An Experimental Study" (unpublished Doctoral dissertation, Department of Speech, Stanford University, 1960).

of vowel intensity, Sacia and Beck, Black, Fairbanks, and Stevens and House; as well as studies utilizing the voice reflex or Lombard effect by Taylor, Black, Hanley and Steer, Korn, Dreher and O'Neill, and Waldron. In all the vowel intensity studies reviewed the emphasis has been the vowel in a consonant setting and therefore consonantal influence has been present. The intensity of isolated vowel sounds has not been studied. Also, there are not any studies of vowel intensity in an environment of noise. In the research involving the Lombard effect the studies have not been limited to intensity of an isolated sound but have dealt in terms of duration, rate, frequency, and intensity with words and continuous speech in noise or communication in noise. The uniqueness then of the present research project is:

1. the measurement of isolated vowel intensity without consonantal influence and in an environment of noise, and
2. a study of the Lombard effect as measured by the intensity of isolated vowel sounds.

CHAPTER III

SUBJECTS, EQUIPMENT, AND PROCEDURES

Introduction

The experiment described in this chapter was accomplished in the sound-treated test room in the Speech and Hearing Science Area of the Department of Speech, Michigan State University, East Lansing, Michigan.

Description of the Subjects

The twelve subjects who participated in this research study were graduate students in Speech and Hearing Science. The subjects were selected on the basis of an expressed interest in research and their availability. The age range of the subjects was 21 years to 46 years, with a mean age of 26.5 years. All subjects had received hearing evaluations and were considered to have normal hearing. None of the subjects knew the purpose of the experiment.

Equipment

The specific equipment employed was:

1. Audiometer (Allison Audiometer Model 20)
2. Headsets (Telephonics TDH-39)
3. Microphone (Electro-voice 654)
4. Tape recorder (Ampex Model 601)

5. Magnetic recording tape (Scotch Tenzar Backing Magnetic Tape 311)
6. Sound level recorder (Gruel and Kjaer Model 2305)
7. Electric timer modified to time at 3 seconds (GraLab Microtimer).

The sounds employed in the study were eleven common American vowels. Included were: [i], [ɪ], [e], [ɛ], [æ], [u], [ʌ], [ɑ], [ɔ], [o], [ʊ]. The vowels were printed phonetically in black on individual white 5 x 8 cards. A one-syllable word was printed beneath each vowel as a clue for those less sophisticated in phonetics (see Appendix).

It has been domonstrated that low noise masking levels (below 45 db) do not seriously influence speech power.[1] Therefore, the specific decibel levels of white noise analyzed in this study were 70, 80, 90, and 100 db (re: 0.0002 microbar).

A form was developed for recording the collected data. The form provided three charts: (1) binaural presentation, (2) monaural presentation (right), and (3) monaural presentation (left). Each chart allowed for recording the intensity of each of the eleven vowels spoken by subjects, at each of the given intensities of white noise (see Appendix).

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[1]Korn, loc. cit.

Procedures for Research

The subjects were seated at a table in the soundproof testing room four feet from the two way window which is located in the wall between the soundproof testing room and the test equipment room. The headset (Telephonics TDH--39) was placed on the subject's ears and he was positioned with his lips seven inches from the microphone (Electrovoice 654). The microphone was connected to the tape recorder (Ampex Model 601). The tape recorder was calibrated prior to the testing of subjects. Also located in the test equipment room was the Allison Model 20 Audiometer. An assistant operated the controls of the Allison Audiometer unit while the researcher located in the test equipment room also, presented the vowel cards to the subjects. The vowel cards along with the microtimer (GraLab) appeared in the glass window for viewing by the subjects. The microtimer was modified to time electrically at 3 seconds, with the red light remaining on for 3 seconds and off for three seconds. The vowel sound was produced for the length of time the light remained on, which was 3 seconds.

All subjects were tested individually. The subject was first seated at the table, four feet from the two-way window in the soundproof testing room and given the following instructions.

> (1) You are to produce the designated vowel sound for the length of time the red light remains on. The red light will remain on for 3 seconds and then be off for 3 seconds. The vowel card will appear in the window next to the light. You will have the

> opportunity to view the next vowel sound for 3 seconds before the light goes on and you are to produce the sound. As you are producing these vowel sounds noise will be fed into your ears. (2) We will review all eleven vowel cards before the actual experimentation procedures are begun. (Vowel cards then practiced.) (3) The first thing you are to do upon receiving a signal from the control room is to give your subject number and name.

Immediately following these instructions the earphones were placed on the subject and his lips placed seven inches from the microphone. The researcher then returned to the test equipment room and began the testing procedure with the aid of the assistant.

Each subject produced each of the eleven vowels, twelve times, at which time they were recorded by a tape recorder (Ampex Model 601). During this procedure white noise was being presented to the ears at 70, 80 90, and 100 db (re: 0.0002 microbar).

Four subjects received the different levels of white noise (1) monaurally-right ear, (2) binaurally, (3) monaurally-left ear; four more received the noise (1) monaurally-left ear, (2) monaurally-right ear, (3) binaurally; and four more received the noise (1) binaurally (2) monaurally-left ear, (3) monaurally-right ear. The order of vowel presentation for each subject was randomized by the use of a random numbers table prior to the experiment time. For example, Subject 1 produced the series of eleven vowels first with the white noise in his right ear and with an intensity of 70, 80, 90, and 100 db (re: 0.0002 microbar). Then he produced the series with the white noise being fed into his ears binaurally with intensity of 70, 80, 90, and 100 db (re: 0.0002 microbar). Finally, he produced the vowel series with white noise in his left ear at the intensity of 70, 80, 90, and 100 db (re:0.0002 microbar). Each time the vowels were presented in a different random order. This meant 12 different orders for 12 subjects with a total of 144 different random orders for the presentation of the vowel sounds.

As the final step in the procedure of the experiment the tapes recorded were employed with the Bruel and Kjaer Model 2305 Sound Level Recorder to obtain the vowel intensity readings in decibels.

CHAPTER IV

RESULTS AND DISCUSSION

Results

The test results were tabulated and tested statistically by use of (1) a two-way analysis of variance (2) a one-way analysis of variance, and (3) *t*-tests in cases where the F from the analysis of variance was significant. It was the purpose of the researcher to analyze the change in vocal intensity of the isolated vowel sounds.

Variation of vowel intensities as a result of degree of masking and mode of presentation.--Two-way analysis of variance was employed to determine if there was significant variance in the isolated vowel intensities as a result of masking and mode of presentation. The computational formulas used in the three two-way analyses of variance are reported in Table 1.

The results of the analyses of vowel intensities as a result of masking and mode of presentation are presented in Tables 2, 3, and 4.

The estimated values of F (v_1 v_2) needed for significance were made from Table A-7C, "Percentiles of the F (v_1 v_2) Distributions," Dixon and Massey.[1]

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[1]Wilfrid J. Dixon and Frank J. Massey, Jr., *Introduction to Statistical Analysis* (New York: McGraw-Hill Book Company, Inc., 1957), 390-403.

TABLE 1

COMPUTATIONAL FORMULAS FOR TWO WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	Mean Square is estimate of
Row Means	$\sum \frac{T.j.^2}{132} - \frac{T...^2}{528}$	r-1 = 3	$\sigma^2 + cn\sigma^2_r$
Column Means	$\sum \frac{Ti..^2}{48} - \frac{T...^2}{528}$	c-1 = 10	$\sigma^2 + rn\sigma^2_c$
Interaction R x C	Subtotal - Rows and Comumns Sum of Squares	(c-1)(r-1) = 30	$\sigma^2 + n\sigma^2_I$
Subtotal	$\sum \frac{Tij.^2}{12} - \frac{T...^2}{528}$	rc-1 = 43	
Within	Total S. S. - Subtotal S. S.	rc (n-1) = 484	σ^2
Total	$\sum_r \sum_{jk} \sum_{ijk} X^2 - \frac{T...^2}{528}$	rcn-1=527	

TABLE 2

BINAURAL MODE OF PRESENTATION
TWO WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	449.09	3	149.69	9.47**
Vowel effect	1420.85	10	142.09	8.99**
N x V Interaction	3712.54	30	123.75	7.83**
Subtotal	4304.48	43		
Within	7652.58	484	15.81	
Total	11057.06	527		

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 3

MONAURAL (RIGHT) MODE OF PRESENTATION
TWO WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	235.6	3	78.5	5.89**
Vowel effect	402.1	10	40.2	3.02**
N x V Interaction	658.6	30	21.9	1.64
Subtotal	1296.3	43		
Within	6446.7	484	13.32	
Total	7743.0	527		

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 4

MONAURAL (LEFT) MODE OF PRESENTATION
TWO WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	22.2	3	7.7	.720
Vowel effect	667.7	10	66.8	6.24 **
N x V Interaction	970.6	30	32.4	3.03 **
Subtotal	1660.5	43		
Within	5195.7	484	10.73	
Total	6856.2	527		

*Significant at .05 level of significance.
**Significant at .01 level of significance.

The tables which follow represent the results of t-tests which were used whenever the F tests in the three two way analyses of variance and twelve one way analyses of variance proved to be significant. These tests are represented in matrix form. In the first matrix, for example, the mean intensity for the vowel in a given row has been subtracted from the mean intensity for the vowel in the corresponding column. In order to determine whether or not these differences are significant, the following computations were made:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{S\sqrt{\frac{1}{N_1} + \frac{1}{N_2}}}$$

whenever the variances σ and σ^2 are equal.

The variances must be assumed to be equal, since this same assumption is made in the analysis of variance. The best estimate of this variance, furthermore, is the within variance is shown in the particular analyses of variance table under consideration. This variance as actually the pooled estimate for all rows and columns. By algebraic manipulation the formula for t becomes:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{S^2\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

TABLE 5

BINAURAL MODE OF PRESENTATION
DIFFERENCE OF MEANS (COLUMNS)

	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
[i]	--	** 2.67	** 3.31	** 4.42	** 4.00	1.52	** 5.00	** 5.71	** 5.44	** 4.48	** 3.77
[I]		--	.64	* 1.75	1.33	-1.15	** 2.33	** 3.04	** 2.77	* 1.81	1.10
[e]			--	1.11	0.69	* -1.79	* 1.69	** 2.40	** 2.13	1.17	0.46
[ɛ]				--	-0.42	** -2.90	0.58	1.29	1.02	0.06	-0.65
[æ]					--	** -2.48	1.00	* 1.71	1.44	0.48	-0.23
[u]						--	** 3.48	** 4.19	** 3.92	** 2.96	** 2.25
[ʌ]							--	0.71	0.44	-0.52	-1.23
[ɑ]								--	-0.27	-1.23	* -1.94
[ɔ]									--	-0.96	* -1.67
[o]										--	-0.71
[ʊ]											--

* Significant at .05 level of significance.
** Significant at .01 level of significance.

TABLE 6

MONAURAL (RIGHT) MODE OF PRESENTATION
DIFFERENCE OF MEANS (COLUMNS)

	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
[i]	--	1.34	1.69*	1.75*	1.60*	1.30	2.59**	2.48**	3.00**	3.21**	2.07**
[I]		--	0.35	0.41	0.08	-0.04	1.25	1.14	1.68*	1.87**	0.73
[e]			--	0.06	-0.27	-0.39	0.9	0.79	1.33	1.52*	0.38
[ɛ]				--	-0.33	-0.45	0.84	0.73	1.27	1.46	0.32
[æ]					--	-0.12	1.17	1.06	1.60*	1.79*	0.65
[u]						--	1.29	1.18	1.72*	1.91*	0.77
[ʌ]							--	-0.11	0.43	0.62	-0.55
[ɑ]								--	0.54	0.73	-0.41
[ɔ]									--	0.19	-0.95
[o]										--	-1.14
[ʊ]											--

* Significant at the .05 level of significance.
** Significant at the .01 level of significance.

TABLE 7

MONAURAL (LEFT) MODE OF PRESENTATION
DIFFERENCE OF MEANS (COLUMNS)

	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
[i]	--	2.21	2.38	2.98	2.08	1.73	3.19	3.38	3.79	3.44	3.09
[ɪ]		--	0.17	0.77	-0.13	-0.48	0.98	1.17	1.58	1.23	0.88
[e]			--	0.60	-0.30	-0.65	0.81	1.00	1.41	1.06	0.71
[ɛ]				--	-0.90	-1.25	0.21	0.40	0.81	0.46	0.11
[æ]					--	-0.35	1.11	1.30	1.71	1.36	1.01
[u]						--	1.46	1.65	2.06	1.71	1.36
[ʌ]							--	0.19	0.60	0.25	-0.10
[ɑ]								--	0.41	0.06	-0.29
[ɔ]									--	-0.35	-0.70
[o]										--	-0.35
[ʊ]											--

* Significant at the .05 level of significance.
** Significant at the .01 level of significance.

TABLE 8

BINAURAL MODE OF PRESENTATION
DIFFERENCE OF MEANS (ROWS)

	70	80	90	100
70	--	0.33	0.58	1.18*
80		--	0.25	0.60
90			--	0.60
100				--

TABLE 9

MONAURAL (RIGHT) MODE OF PRESENTATION
DIFFERENCES OF MEANS (ROWS)

	70	80	90	100
70	--	0.50	1.22**	1.51**
80		--	0.72	1.01*
90			--	0.29
100				--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

Variation among intensity levels of the eleven common American vowels as a result of mode of presentation. One way analyses of variance were used to determine if there was a significant variance of intensity within responses of subjects to each vowel sound as a result of mode of presentation. When the F's were significant the *t*-test, as described previously, was used. The computational formulas used are presented in Table 10.

TABLE 10

COMPUTATIONAL FORMULA FOR ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	Mean Square is Estimate of:
Means	$\sum_{j} \frac{T_i^2}{n_i} - \frac{T_{..}^2}{N}$	K - 1	$\sigma^2 + n\sigma_m^2$
Within	$\sum_{i}\sum_{j} X_{ij}^2 - \sum_{j} \frac{T_{i.}^2}{n_i}$	N - K	σ^2
Total	$\sum\sum_{ij} X_{ij}^2 - \frac{T_{..}^2}{N}$	N - 1	

The results of these analyses and *t*-tests are reported in Tables 11-31.

TABLE 11

MODES OF PRESENTATION FOR VOWEL [i]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	234.37	2	117.19	0.944
Within	17495.37	141	124.09	
Total	17729.75	143		

TABLE 12

MODES OF PRESENTATION FOR VOWEL [I]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	321.78	2	160.89	1.2137
Within	18690.86	141	132.56	
Total	19012.64	143		

*Significant at .05 level of significance.
**Significant at .01 level of significance.

TABLE 13

MODES OF PRESENTATION FOR VOWEL [e]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	389.77	2	194.88	21.81**
Within	128.79	141	8.94	
Total	1676.56	143		

TABLE 14

MODES OF PRESENTATION FOR VOWEL [e]
t-TEST

	Binaural	Monaural (R)	Monaural (L)
Binaural	--	-2.89	-3.87*
Monaural (R)		--	- .98
Monaural (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 15

MODES OF PRESENTATION FOR VOWEL [ɛ]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	547.91	2	273.95	19.31**
Within	2001.03	141	14.19	
Total	2548.94	143		

TABLE 16

MODES OF PRESENTATION FOR VOWEL [ɛ]
t-TEST

	B	M (R)	M (L)
B	--	-3.93**	-4.13**
M (R)		--	-0.3
M (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 17

MODES OF PRESENTATION FOR VOWEL [æ]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	634.68	2	317.34	18.76**
Within	2384.87	141	16.92	
Total	3019.55	143		

TABLE 18

MODES OF PRESENTATION FOR VOWEL [æ]
t-TEST

	B	M (R)	M (L)
B	--	3.94**	-4.84**
M (R)		--	-0.90
M (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 19

MODES OF PRESENTATION FOR VOWEL [u]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	177.73	2	88.83	7.61**
Within	1645.58	141	11.67	
Total	1823.31	143		

TABLE 20

MODES OF PRESENTATION FOR VOWEL [u]
t-TEST

	B	M (R)	M (L)
B	--	-1.59*	-2.71
M (R)		--	-1.12
M (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 21

MODES OF PRESENTATION FOR VOWEL [ʌ]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	600.04	2	300.3	13.72**
Within	3091.40	141	21.93	
Total	3691.44	143		

TABLE 22

MODES OF PRESENTATION FOR VOWEL [ʌ]
t-TEST

	B	M (R)	M (L)
B	--	-3.77**	-4.72**
M (R)		--	-0.95
M (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 23

MODES OF PRESENTATION FOR VOWEL [ɑ]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	784.23	2	392.12	12.63**
Within	4377.10	141	31.04	
Total	5161.33	143		

TABLE 24

MODES OF PRESENTATION FOR VOWEL [ɑ]
t-TEST

	B	M (R)	M (L)
B	--	-4.58**	-5.25**
M (R)		--	-0.67
M (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 25

MODES OF PRESENTATION FOR VOWEL [ɔ]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	570.60	2	285.30	12.64**
Within	3181.62	141	22.57	
Total	3752.22	143		

TABLE 26

MODES OF PRESENTATION FOR VOWEL [ɔ]
t-TEST

	B	M (R)	M (L)
B	--	-3.77**	-4.56**
M (R)		--	-0.74
M (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 27

MODES OF PRESENTATION FOR VOWEL [O]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	425.39	2	212.69	18.39**
Within	1629.92	141	11.56	
Total	2055.31	143		

TABLE 28

MODES OF PRESENTATION FOR VOWEL [O]
t-TEST

	B	M (R)	M (L)
B	--	-2.79**	-4.12**
M (R)		--	-1.23
M (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 29

MODES OF PRESENTATION FOR VOWEL [ʊ]
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	366.05	2	183.02	11.63**
Within	2219.42	141	15.74	
Total	2585.47	143		

TABLE 30

MODES OF PRESENTATION FOR VOWEL [ʊ]
t-TEST

	B	M (R)	M (L)
B	--	-3.10**	-3.61**
M (R)		--	-0.51
M (L)			--

*Significant at the .05 level of significance.
**Significant at the .01 level of significance.

TABLE 31

MODES OF PRESENTATION FOR ALL VOWELS COMBINED
ONE WAY ANALYSIS OF VARIANCE

Source	Sum of Squares	df	M. S.	F
White noise effect	14861	2	7431.5	1819.22**
Within	6417	1571		
Total	21378	1573		

Discussion

The results of the two way analysis of variance for binaural mode of presentation and monaural (right) mode of presentation demonstrate: (1) the mean intensity of utterances corresponding to the four intensities of white noise differ significantly at the .01 level of significance; (2) the mean intensity of utterances corresponding to the eleven vowels differ significantly at the .01 level of significance; and (3) there is interaction between vowels of intensity of white noise at the .01 level of significance. Tables 5 and 6 represent the results of the _t_-tests and show the significance of differences among the specific vowel sounds. It is worthwhile to note the contrast in number of significant differences in means at both the .05 level and .01 level of significance illustrated by Tables 5 and 6.

The two way analysis of variance used for monaural (left) mode of presentation yields, in part, different results. It was determined the mean intensity of utterances corresponding to the four intensities of white noise do not differ significantly at the .05 level of significance. The remainder of the results correspond with those found in the binaural and monaural (right) modes of presentation. The findings through use of the t-test are reported in Table 7. It is interesting to note, there are again fewer significant differences in the mean intensities of the eleven vowel sounds at both the .05 and .01 levels of significance than found in the binaural mode of presentation.

Tables 8 and 9 illustrate the differences of means in terms of white noise, of binaural mode of presentation and monaural (right) mode of presentation. In the binaural made of presentation there was a significant difference between the levels of 70db and 100db, at the .05 level of significance. There were more and greater differences in the monaural (right) mode of presentation. It was found that there were significant differences between: (1) 70 db and 90 db at the .01 level of significance; (2) 70 db and 100 db at the .01 level of significance; and (3) 80 db and 100 db at the .05 level of significance.

One way analyses of variance were used with each of the eleven vowels to determine whether significant differences resulted from binaural, right and left presentations. The results of these analyses and corresponding t-tests, in cases of significance, are represented in Tables 11-30.

Vowels [i] and [ɪ] demonstrated no significant change in intensity as a result of the varied modes of presentation. The other vowel sounds, [e], [ɛ], [æ], [u], [ʌ], [ɑ], [ɔ], [o], and [ʊ], showed significant differences at the .01 level of significance. The significant and non-significant differences between modes of presentation for the nine sugnificant difference vowels are presented in table form along with the analyses of variance results.

Table 31 illustrates the results of the analysis variance of the eleven vowels combined with regard to mode of presentation. The mean intensities for the three different modes of presentation differ significantly from one another.

To further illustrate the data discussed, graphic representations of the results follow (Figures 1-15).

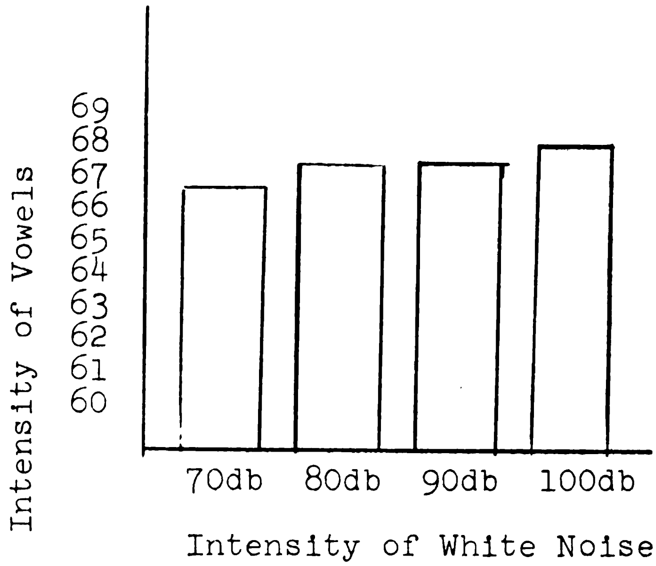

Figure 1--Intensity of Vowels--Binaural Presentation
Varied Intensities White Noise

Figure 1 shows the increase of mean intensity (voice reflex) of the vowel sounds as a result of masking presented binaurally.

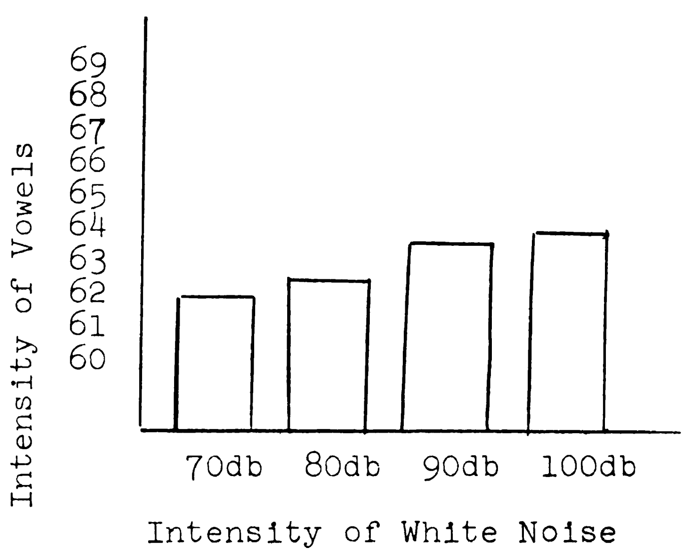

Figure 2--Intensity of Vowels--Monaural (Right)
Presentation--Varied Intensities White Noise

Figure 2 shows the increase of mean intensity (voice reflex) of the vowel sounds as a result of masking being presented to the right ear.

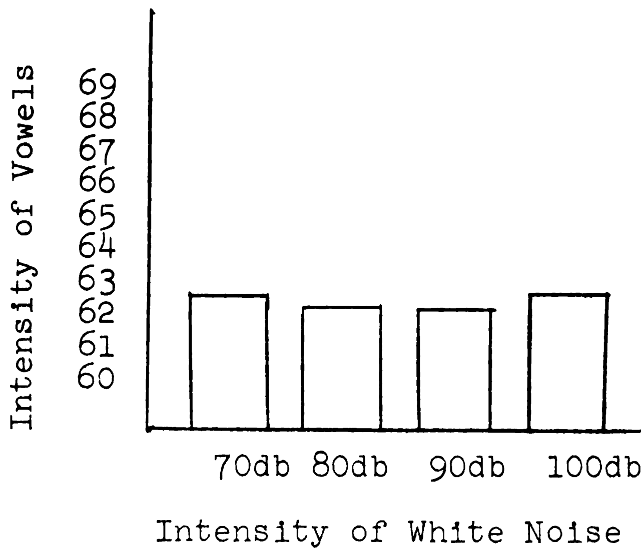

Figure 3--Intensity of Vowels--Monaural (Left) Presentation Varied Intensities White Noise

Figure 3 illustrates the irregular pattern of the increase and decrease of mean intensity (voice reflex) of the vowel sounds as a result of masking being presented to the left ear.

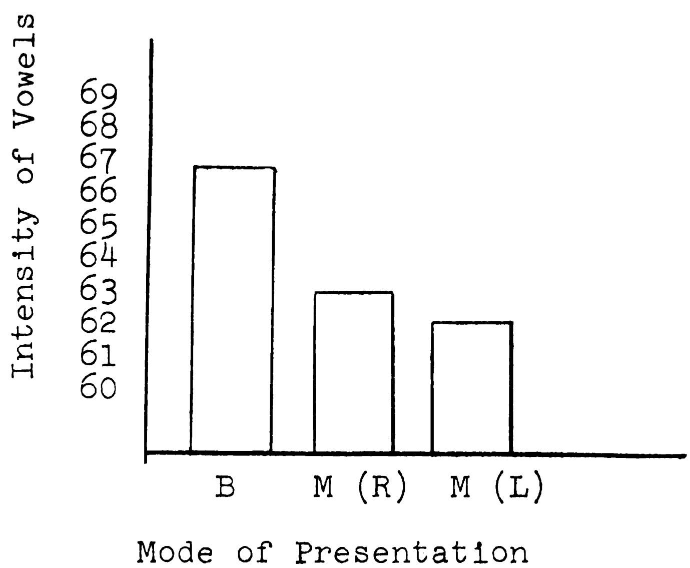

Figure 4--Combined Vowel Sounds--Modes of Presentation

Figure 4 demonstrates that the mean intensity of the vowel sounds was greatest during binaural presentation. The figure also shows the vowels were greater during monaural (right) presentation than during monaural (left) presentation.

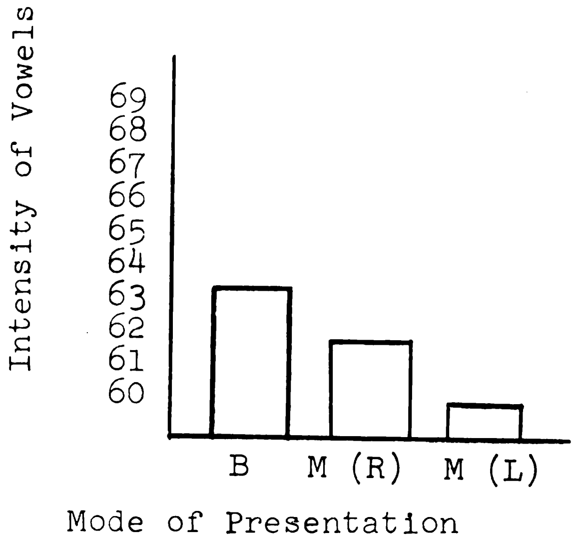

Figure 5--Vowel[i] Modes in Presentation

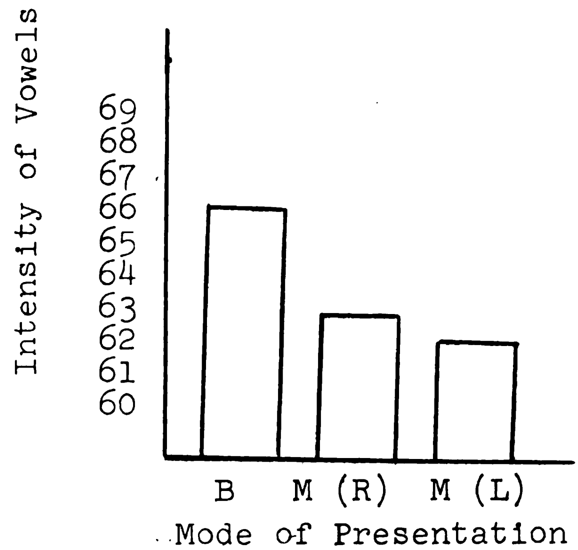

Figure 6--Vowel[I] Modes in Presentation

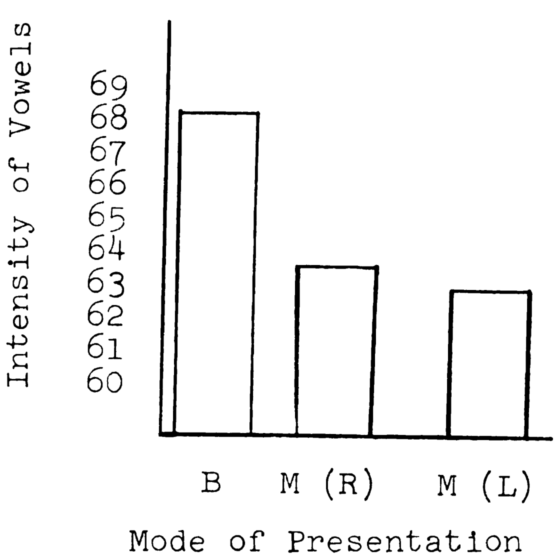

Figure 7--Vowel[ɛ] Modes in Presentation

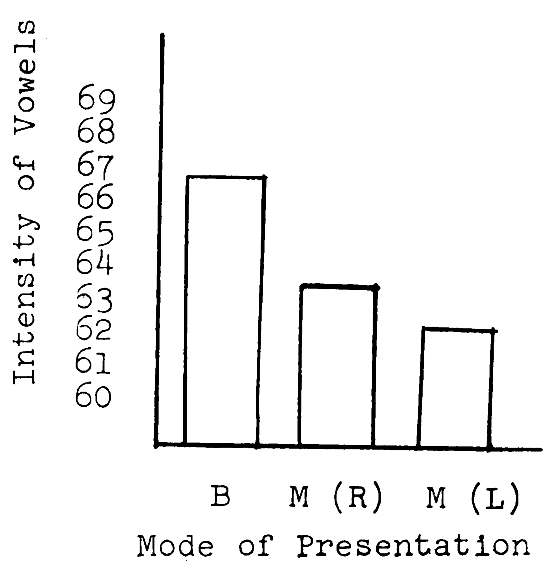

Figure 8--Vowel[e] Modes in Presentation

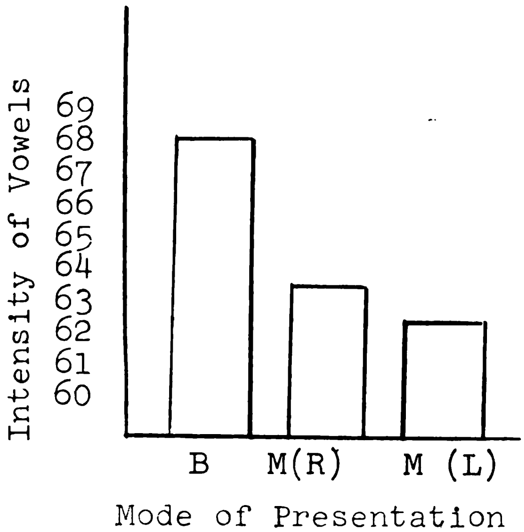

Figure 9--Vowel[æ] Modes in Presentation

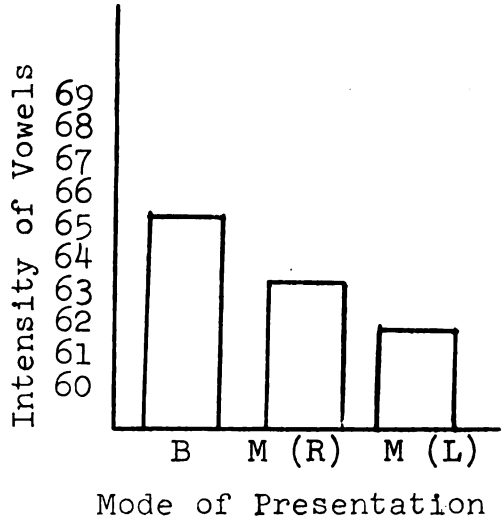

Figure 10--Vowel [u] Modes in Presentation

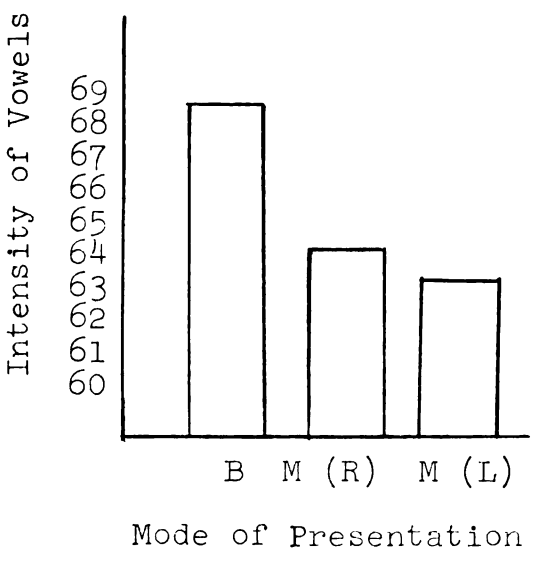

Figure 11--Vowel[ʌ]Modes in Presentation

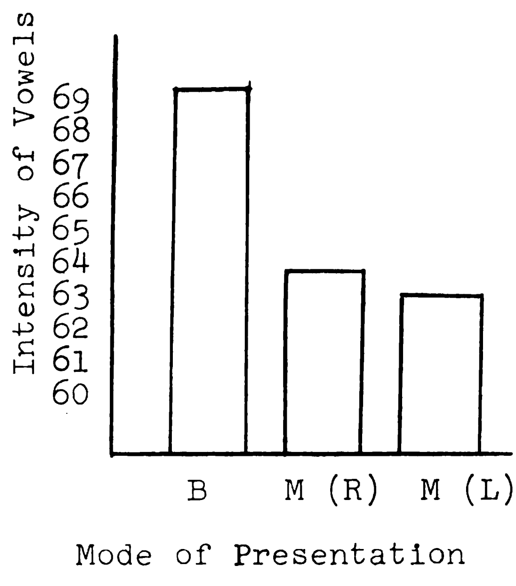

Figure 12--Vowel [a] Modes in Presentation

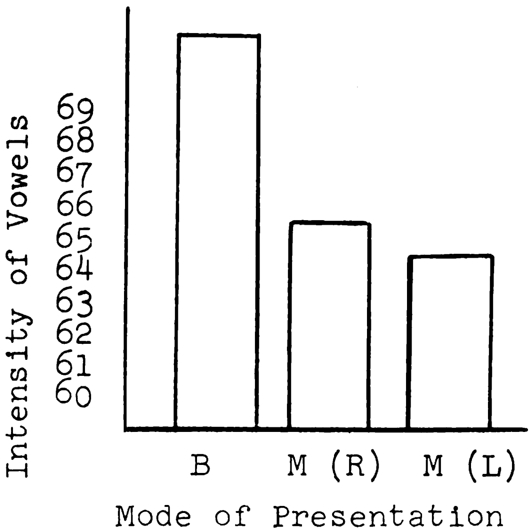

Figure 13--Vowel [ɔ] Modes in Presentation

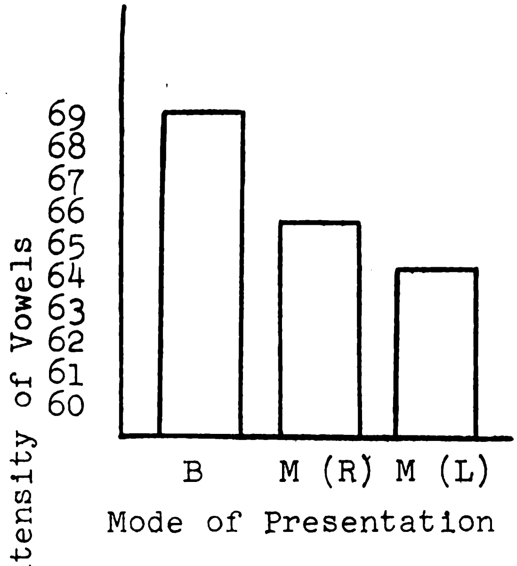

Figure 14--Vowel [o] Modes in Presentation

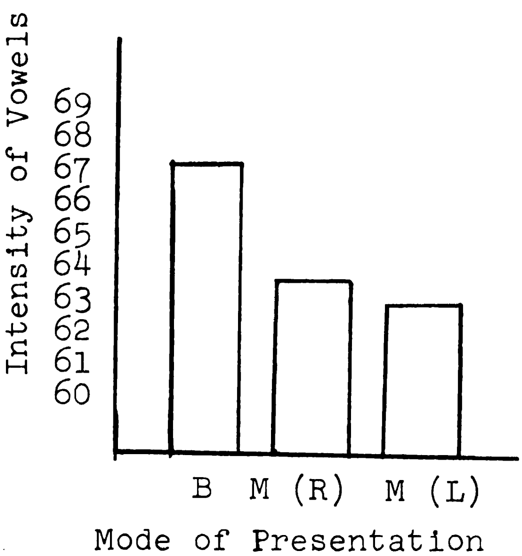

Figure 15--Vowel [ʌ] Modes of Presentation

Figures 5-15 illustrate the effect of binaural masking in contrast to monaural (right and left) presentations.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

It was the purpose of this research study to determine the relationship between the Lombard effect and vowel intensity with respect to specific questions. The questions proposed were:

1. How intense is the voice reflex for each isolated vowel sound when specific levels of white noise (masking) are presented to the right and left ears?
2. How intense is the voice reflex for each isolated vowel sound when specific levels of white noise (masking) are presented binaurally?
3. Is there a significant difference in the intensity of the voice reflex on vowel sounds between the binaural and monaural masking?
4. Is there a systematic intensity pattern that characterizes the eleven spoken vowel sounds?

The review of literature included previous vowel intensity studies and Lombard effect studies. It was evident from this review that numerous studies had been conducted on the measurement of vowel intensity as well as research based on the Lombard effect. In all the vowel intensity studies the emphasis had been on the vowel in a consonant setting. The research concerned with the Lombard effect were not limited to intensity of an isolated sound but dealt in terms of duration, rate, frequency, and intensity with words and continuous speech in noise or communication in noise.

Twelve, normal hearing, graduate students in Speech and Hearing Science, Michigan State University were used as subjects in the experiment. Equipment used consisted of (1) an audiometer, (Allison Model 20); (2) headset, (Telephonics TDH-39); (3) a microphone, (4) tape recorder, (Ampex Model 601); (5) recording tape, (Scotch Tenzar Backing Magnetic Tape 311); (6) sound level recorder, (Bruel and Kjaer Model 2305); and (7) a modified electric timer, (GraLab Microtimer). The twelve subjects produced a series of eleven randomized vowels at which time white noise was fed into their ears, binaurally, right and left at 70, 80, 90, and 100 db (re: 0.0002 microbar).

The results of the research study suggest that the intensity of spoken vowels may be significantly effected by intensity of masking being presented to the ears and by the mode in which this making is presented.

Conclusions

Within the experimental arrangements of this study the following conclusions appear to be in order.

1. There is a significant difference in the mean intensity of the spoken vowels corresponding to the four intensities of white noise when the white noise is presented binaurally or to the right ear. There is not a significant difference in the mean intensity of the spoken vowels corresponding to the four intensities of white noise when the white noise is presented to the left ear.

2. The mean intensity of the eleven spoken vowels differ significantly when the white noise is presented binaurally, and to the right and left ears.

3. There is an interaction between the eleven spoken vowels and the intensity of white noise presented to the ears. This interaction is significant when the white noise is presented binaurally, and to the right and left ears.

4. The spoken vowels [i] and[ɪ] did not show a significant change in intensity as a result of binaural, or right and left presentation of the white noise.

5. The spoken vowels [e],[ɛ] ,[æ] ,[u], [ʌ],[ɑ],[ɔ],[o], and [ʊ]showed significant differences in intensity as a result a binaural, or right and left presentation of the white noise.

6. There is a significant difference in the mean intensities for the binaural, left and right modes of presentation.

7. The eleven spoken vowels demonstrated a greater mean intensity when the white noise was presented binaurally in contrast to right and left ear presentation.

Implications for Further Research

The following questions might well be considered for further research.

1. What would be the effect on the voice reflex if the order of intensities of white noise presentations were changed for each subject?

2. Is there an effect on the intensity of vowels with regard to placement in the series of vowels for production?

3. Is fatigue a factor in the degree of voice reflex exhibited, and if so, to what extent?

4. What specific characteristics in production of vowel sounds causes a significant or nonsignificant response to masking?

APPENDIX A

APPENDIX A

Sample of Eleven Vowel Cards for Presentation

[i]
feet

[ɪ]
fit

[e]
cape

[ɛ]
set

[æ]
cat

[u]
soup

[ʌ]
cup

[ɑ]
cot

[ɔ]
caught

[o]
coat

[ʊ]
cook

APPENDIX B

Random Order of Vowel Cards for Presentation

Subject (1) R B L

R - 70	[ɔ],	[i],	[ɑ],	[u],	[æ],	[ɛ],	[o],	[ʌ],	[ʊ],	[e],	[ɪ]
80	[o],	[ʌ],	[ɛ],	[æ],	[ɔ],	[e],	[ɪ],	[ɑ],	[u],	[ʊ],	[i]
90	[ʊ],	[ɛ],	[ɔ],	[e],	[ɑ],	[i],	[ʌ],	[æ],	[o],	[u],	[ɪ]
100	[u],	[ɛ],	[ʌ],	[æ],	[i],	[e],	[ɪ],	[ɑ],	[o],	[ʊ],	[ɔ]
B - 70	[ɛ],	[o],	[ɑ],	[e],	[ʌ],	[ɔ],	[æ],	[ʊ],	[ɪ],	[i],	[u]
80	[ɔ],	[ɛ],	[e],	[ɑ],	[u],	[ɪ],	[ʌ],	[ʊ],	[i],	[æ],	[o]
90	[ʌ],	[æ],	[ɛ],	[i],	[o],	[ɪ],	[ɑ],	[e],	[ʊ],	[u],	[ɔ]
100	[e],	[ɑ],	[ɔ],	[ɪ],	[ʌ],	[o],	[æ],	[u],	[ɛ],	[ʊ],	[i]
L - 70	[ɔ],	[ɑ],	[ʌ],	[ɛ],	[ɪ],	[æ],	[ʊ],	[e],	[u],	[i],	[o]
80	[i],	[ɔ],	[u],	[ʊ],	[e],	[æ],	[ɛ],	[ɪ],	[ɑ],	[o],	[ʌ]
90	[u],	[e],	[ʌ],	[ɪ],	[ɔ],	[æ],	[o],	[ɛ],	[ɑ],	[ʊ],	[i]
100	[ɪ],	[e],	[ɛ],	[ʊ],	[ʌ],	[u],	[ɑ],	[i],	[ɔ],	[o],	[æ]

Random Order of Vowel Cards for Presentation

Subject (2) L R B

L - 70	[ɑ],	[ɛ],	[ɔ],	[u],	[i],	[ʌ],	[e],	[o],	[ʊ],	[æ],	[ɪ]
80	[ɔ],	[ɛ],	[u],	[ɑ],	[e],	[ʌ],	[æ],	[ɪ],	[o],	[ʊ],	[i]
90	[u],	[æ],	[ʊ],	[ɛ],	[ɔ],	[i],	[e],	[ɪ],	[ɑ],	[o],	[ʌ]
100	[ɔ],	[u],	[i],	[ɛ],	[o],	[ʌ],	[ɑ],	[ɪ],	[æ],	[ʊ],	[e]
R - 70	[æ],	[u],	[o],	[ʊ],	[ɪ],	[ɑ],	[ɔ],	[i],	[e],	[ɛ],	[ʌ]
80	[ɛ],	[ʊ],	[æ],	[ɔ],	[ʌ],	[i],	[ɪ],	[u],	[e],	[o],	[ɑ]
90	[ʌ],	[ɛ],	[o],	[i],	[o],	[u],	[ɑ],	[ʊ],	[ɪ],	[e],	[æ]
100	[ɑ],	[ʌ],	[o],	[e],	[u],	[ɪ],	[æ],	[ɛ],	[o],	[ʊ],	[i]
B - 70	[ɛ],	[e],	[ɑ],	[u],	[ɔ],	[ʊ],	[ʌ],	[i],	[ɪ],	[o],	[æ]
80	[ɔ],	[i],	[ɑ],	[ɪ],	[u],	[ʌ],	[æ],	[o],	[ɛ],	[ʊ],	[e]
90	[ɛ],	[u],	[ʌ],	[ɪ],	[æ],	[ɔ],	[e],	[ɑ],	[o],	[ʊ],	[i]
100	[ɑ],	[ʊ],	[ʌ],	[ɔ],	[ɛ],	[i],	[u],	[æ],	[ɪ],	[e],	[o]

Random Order of Vowel Cards for Presentation

Subject (3) B L R

B - 70	[ɛ],	[ɪ],	[ɔ],	[ɑ],	[e],	[æ],	[u],	[i],	[o],	[ʌ],	[ʊ]
80	[ɔ],	[ɑ],	[e],	[ɛ],	[ɪ],	[o],	[æ],	[ʌ],	[ʊ],	[u],	[i]
90	[ɑ],	[ʌ],	[æ],	[ɛ],	[ɔ],	[e],	[ɪ],	[u],	[ʊ],	[i],	[o]
100	[u],	[ʌ],	[i],	[ɛ],	[o],	[æ],	[ɪ],	[e],	[ɑ],	[ɔ],	[ʊ]
L - 70	[ɔ],	[ɔ],	[æ],	[ɛ],	[ʌ],	[e],	[ɑ],	[ɪ],	[u],	[ʊ],	[i]
80	[ʌ],	[ɛ],	[ɪ],	[u],	[ɑ],	[æ],	[e],	[ɔ],	[ʊ],	[i],	[o]
90	[i],	[ɑ],	[ɔ],	[æ],	[ɛ],	[ɪ],	[u],	[ʌ],	[o],	[e],	[ʊ]
100	[ɔ],	[ɑ],	[ʌ],	[e],	[æ],	[ɪ],	[u],	[ɛ],	[o],	[ʊ],	[i]
R - 70	[æ],	[e],	[ʌ],	[ɪ],	[ɑ],	[ʊ],	[u],	[o],	[ɛ],	[i],	[ɔ]
80	[æ],	[u],	[i],	[ʌ],	[ɪ],	[ɛ],	[ɔ],	[o],	[ʊ],	[e],	[ɑ]
90	[ʌ],	[e],	[ɑ],	[ɔ],	[ɪ],	[u],	[o],	[ʊ],	[æ],	[ɛ],	[i]
100	[ɔ],	[ɑ],	[e],	[ʊ],	[ʌ],	[æ],	[u],	[ɪ],	[i],	[ɛ],	[o]

Random Order of Vowel Cards for Presentation

Subject (4) R B L

R - 70	[ɛ],	[ɪ],	[e],	[ɔ],	[i],	[u],	[o],	[æ],	[ʌ],	[ɑ],	[ʊ]
80	[e],	[ʌ],	[o],	[ʊ],	[ɛ],	[i],	[ɑ],	[ɔ],	[u],	[ɪ],	[æ]
90	[ɔ],	[u],	[ʊ],	[i],	[æ],	[ɑ],	[ɛ],	[ɪ],	[o],	[ʌ],	[e]
100	[u],	[æ],	[ɛ],	[ɪ],	[i],	[ɑ],	[o],	[ʊ],	[ʌ],	[e],	[ɔ]
B - 70	[ʌ],	[æ],	[ɑ],	[u],	[ɔ],	[e],	[o],	[ʊ],	[ɛ],	[ɪ],	[i]
80	[u],	[ɪ],	[æ],	[ɛ],	[ʌ],	[ʊ],	[ɑ],	[e],	[ɔ],	[i],	[o]
90	[i],	[e],	[æ],	[ɑ],	[u],	[o],	[ɛ],	[ʌ],	[ʊ],	[ɪ],	[ɔ]
100	[ɛ],	[æ],	[ɔ],	[u],	[ɑ],	[ʌ],	[o],	[e],	[ʊ],	[i],	[ɪ]
L - 70	[ɑ],	[ɔ],	[æ],	[ʊ],	[ʌ],	[ɪ],	[e],	[i],	[o],	[ɛ],	[u]
80	[ɔ],	[e],	[u],	[ʌ],	[ɛ],	[æ],	[ɑ],	[i],	[ɪ],	[o],	[ʊ]
90	[ʌ],	[ɪ],	[ɛ],	[o],	[e],	[ɔ],	[u],	[æ],	[ʊ],	[ɑ],	[i]
100	[ɔ],	[ʊ],	[i],	[ɑ],	[o],	[ʌ],	[u],	[e],	[ɛ],	[ɪ],	[æ]

Random Order of Vowel Cards for Presentation

Subject (5) L R B

L - 70	[e],	[ɛ],	[æ],	[ɑ],	[i],	[ɔ],	[ʌ],	[ɪ],	[u],	[o],	[ʊ]
80	[e],	[ɪ],	[ɛ],	[æ],	[ʌ],	[o],	[ɑ],	[ɔ],	[u],	[ʊ],	[i]
90	[e],	[ʌ],	[ɑ],	[ɛ],	[æ],	[ʊ],	[u],	[i],	[ɪ],	[ɔ],	[o]
100	[æ],	[e],	[u],	[ɛ],	[ʌ],	[ɔ],	[ɪ],	[ɑ],	[i],	[o],	[ʊ]
R - 70	[ɛ],	[u],	[ɪ],	[æ],	[ɔ],	[ɑ],	[o],	[ʊ],	[ʌ],	[e],	[i]
80	[ɛ],	[ɪ],	[e],	[ʌ],	[æ],	[ɑ],	[ʊ],	[i],	[o],	[u],	[ɔ]
90	[i],	[o],	[æ],	[ɛ],	[ɪ],	[ʌ],	[ɔ],	[u],	[ɑ],	[e],	[ʊ]
100	[e],	[ɛ],	[ɔ],	[æ],	[u],	[ɑ],	[ɪ],	[ʌ],	[o],	[ʊ],	[i]
B - 70	[ʊ],	[e],	[u],	[ɪ],	[ɑ],	[ɔ],	[æ],	[ʌ],	[i],	[ɛ],	[o]
80	[ɔ],	[u],	[e],	[ʌ],	[o],	[i],	[ɪ],	[æ],	[ɛ],	[ʊ],	[ɑ]
90	[ɑ],	[u],	[ɔ],	[ʌ],	[ɛ],	[æ],	[ɪ],	[ʊ],	[o],	[e],	[i]
100	[ɛ],	[i],	[ɪ],	[ɑ],	[u],	[æ],	[ʊ],	[ʌ],	[e],	[ɔ],	[o]

Random Order of Vowel Cards for Presentation

Subject (6) B L R

B - 70	[u],	[e],	[ɛ],	[ʌ],	[ɪ],	[o],	[æ],	[ɔ],	[i],	[ɑ],	[ʊ]
80	[e],	[ɛ],	[ɪ],	[ɑ],	[u],	[æ],	[ʊ],	[ɔ],	[ʌ],	[i],	[o]
90	[o],	[i],	[ʌ],	[ʊ],	[e],	[ɛ],	[æ],	[u],	[ɔ],	[ɑ],	[ɪ]
100	[u],	[e],	[ɪ],	[ʌ],	[ɛ],	[ʊ],	[i],	[ɔ],	[o],	[æ],	[ɑ]
L - 70	[æ],	[ɔ],	[ɪ],	[i],	[e],	[ʌ],	[o],	[ʊ],	[ɛ],	[ɑ],	[u]
80	[o],	[u],	[ʌ],	[ɛ],	[æ],	[ɑ],	[ɔ],	[ɪ],	[e],	[ʊ],	[i]
90	[u],	[ɑ],	[ɔ],	[o],	[ɛ],	[e],	[ʌ],	[æ],	[i],	[ʊ],	[ɪ]
100	[ɑ],	[e],	[u],	[ʌ],	[ʊ],	[ɔ],	[æ],	[ɪ],	[o],	[i],	[ɛ]
R - 70	[o],	[ɪ],	[i],	[ʊ],	[ɔ],	[u],	[ɑ],	[æ],	[ɛ],	[e],	[ʌ]
80	[o],	[e],	[ʊ],	[u],	[ɑ],	[ɔ],	[æ],	[ɛ],	[i],	[ɪ],	[ʌ]
90	[ɪ],	[ɔ],	[æ],	[ɛ],	[ɑ],	[e],	[ʌ],	[i],	[ʊ],	[u],	[o]
100	[o],	[ʌ],	[ʊ],	[i],	[ɑ],	[ɪ],	[ɔ],	[u],	[æ],	[ɛ],	[e]

Random Order of Vowel Cards for Presentation

Subject (7) R B L

R - 70	[i],	[ɑ],	[u],	[ɔ],	[ɪ],	[ɛ],	[ʊ],	[æ],	[e],	[ʌ],	[o]
80	[ɪ],	[ɔ],	[ɑ],	[ʊ],	[o],	[æ],	[i],	[ʌ],	[e],	[ɛ],	[u]
90	[u],	[æ],	[i],	[o],	[ʌ],	[ɪ],	[ʊ],	[ɑ],	[e],	[ɔ],	[ɛ]
100	[ɛ],	[ʌ],	[ɑ],	[e],	[ɪ],	[æ],	[ʊ],	[i],	[o],	[ɔ],	[u]
B - 70	[ɪ],	[i],	[e],	[u],	[æ],	[ɑ],	[ɛ],	[ɔ],	[ʌ],	[o],	[ʊ]
80	[ʊ],	[u],	[ʌ],	[e],	[ɑ],	[æ],	[ɪ],	[o],	[ɛ],	[ɔ],	[i]
90	[ɔ],	[o],	[u],	[ʌ],	[ɪ],	[i],	[æ],	[e],	[ʊ],	[ɛ],	[ɑ]
100	[o],	[ɛ],	[u],	[ʊ],	[i],	[ʌ],	[ɪ],	[e],	[ɔ],	[ɑ],	[æ]
L - 70	[e],	[ɛ],	[ʌ],	[ɑ],	[æ],	[ɔ],	[o],	[i],	[ʊ],	[u],	[ɪ]
80	[ɪ],	[ʌ],	[o],	[ɛ],	[æ],	[u],	[e],	[ʊ],	[i],	[ɑ],	[ɔ]
90	[e],	[ɛ],	[o],	[u],	[ɔ],	[æ],	[ɪ],	[ɑ],	[i],	[ʊ],	[ʌ]
100	[ɑ],	[ɛ],	[ɪ],	[ʊ],	[o],	[i],	[u],	[e],	[ɔ],	[ʌ],	[æ]

<u>Random Order of Vowel Cards for Presentation</u>

Subject (8) L R B

L - 70	[u],	[æ],	[ɛ],	[ɔ],	[i],	[ɑ],	[ʊ],	[ʌ],	[e],	[o],	[ɪ]
80	[ɛ],	[æ],	[o],	[ɔ],	[ʌ],	[u],	[ɪ],	[ʊ],	[i],	[e],	[ɑ]
90	[æ],	[o],	[ɪ],	[ɛ],	[e],	[ɔ],	[u],	[ʌ],	[i],	[ʊ],	[ɑ]
100	[ɛ],	[ɑ],	[æ],	[ɔ],	[ɪ],	[ʊ],	[o],	[ɪ],	[e],	[u],	[ʌ]
R - 70	[e],	[ɑ],	[ɪ],	[u],	[i],	[æ],	[ɛ],	[ʊ],	[o],	[ɔ],	[ʌ]
80	[ɛ],	[ʌ],	[u],	[æ],	[ʊ],	[e],	[ɑ],	[ɔ],	[o],	[i],	[ɪ]
90	[æ],	[ɪ],	[o],	[u],	[ɛ],	[ʌ],	[e],	[ɔ],	[ɑ],	[i],	[ʊ]
100	[ʊ],	[i],	[ɪ],	[ɛ],	[ʌ],	[ɑ],	[e],	[æ],	[ɔ],	[u],	[o]
B - 70	[o],	[ʌ],	[ɑ],	[i],	[ɔ],	[ɛ],	[e],	[ʊ],	[u],	[æ],	[ɪ]
80	[u],	[ʌ],	[o],	[æ],	[e],	[ɑ],	[ɔ],	[ʊ],	[ɛ],	[ɪ],	[i]
90	[ɛ],	[u],	[ʌ],	[o],	[ɔ],	[ɑ],	[æ],	[ɪ],	[e],	[i],	[ʊ]
100	[e],	[æ],	[ɛ],	[ɪ],	[æ],	[ʊ],	[o],	[i],	[u],	[ɔ],	[ʌ]

Random Order of Vowel Cards for Presentation

Subject (9) B L R

B - 70	[ɔ],	[ʌ],	[u],	[ɛ],	[i],	[ɑ],	[e],	[ʊ],	[æ],	[ɪ],	[o]
80	[o],	[ɛ],	[ɑ],	[ɪ],	[ɔ],	[e],	[ʌ],	[u],	[æ],	[ʊ],	[i]
90	[ɔ],	[ʌ],	[ɪ],	[ɛ],	[o],	[e],	[ɑ],	[æ],	[u],	[i],	[ʊ]
100	[æ],	[ɑ],	[ʊ],	[o],	[ɪ],	[ɔ],	[ɛ],	[e],	[u],	[ʌ],	[i]
L - 70	[u],	[e],	[ɪ],	[o],	[ɑ],	[i],	[ʊ],	[æ],	[ʌ],	[ɛ],	[ɔ]
80	[ɛ],	[ʊ],	[ʌ],	[ɔ],	[æ],	[ɑ],	[ɪ],	[i],	[e],	[o],	[u]
90	[ɔ],	[i],	[ʊ],	[o],	[æ],	[u],	[ʌ],	[ɛ],	[e],	[ɑ],	[ɪ]
100	[e],	[ɔ],	[ɪ],	[ɑ],	[o],	[ɛ],	[ʌ],	[u],	[æ],	[ʊ],	[i]
R - 70	[ɛ],	[ɔ],	[ʌ],	[u],	[ɑ],	[o],	[e],	[æ],	[i],	[ɪ],	[ʊ]
80	[ɛ],	[ɪ],	[ʌ],	[u],	[ʊ],	[æ],	[ɑ],	[i],	[o],	[e],	[ɔ]
90	[i],	[u],	[e],	[ɔ],	[ɛ],	[ʊ],	[ɑ],	[ɪ],	[ʌ],	[æ],	[o]
100	[u],	[æ],	[ɔ],	[ɑ],	[ʌ],	[ʊ],	[i],	[e],	[ɪ],	[ɛ],	[o]

Random Order of Vowel Cards for Presentation

Subject (10) R B L

R - 70	[ʌ], [I], [æ], [ɑ], [i], [ɔ], [ʊ], [o], [ɛ], [e], [u]
80	[I], [ɔ], [u], [o], [æ], [ɑ], [ʊ], [ʌ], [i], [e], [ɛ]
90	[ɛ], [i], [ɑ], [ɔ], [e], [I], [ʊ], [ʌ], [o], [u], [æ]
100	[ʊ], [i], [ɛ], [ʌ], [ɑ], [u], [e], [I], [o], [ɔ], [æ]
B - 70	[e], [æ], [o], [ʌ], [u], [I], [ɛ], [ɔ], [i], [ʊ], [ɑ]
80	[ɔ], [I], [ɛ], [e], [ʌ], [ʊ], [ɑ], [æ], [o], [i], [u]
90	[ɑ], [ɔ], [I], [u], [i], [ʊ], [ɛ], [o], [ʌ], [e], [æ]
100	[ɛ], [ʌ], [ɔ], [æ], [ʊ], [o], [u], [I], [i], [ɑ], [e]
L - 70	[e], [I], [ʌ], [i], [u], [ɑ], [ʊ], [ɛ], [ɔ], [æ], [o]
80	[ʊ], [e], [u], [ʌ], [ɔ], [i], [o], [ɛ], [ɑ], [I], [æ]
90	[æ], [o], [i], [ʌ], [u], [ɔ], [e], [ɛ], [I], [ʊ], [ɑ]
100	[ʊ], [e], [ʌ], [u], [ɔ], [i], [o], [ɛ], [ɑ], [æ], [I]

Random Order of Vowel Cards for Presentation

Subject (11) L R B

L - 70 [ɑ], [ɔ], [ɪ], [æ], [i], [u], [o], [e], [ɛ], [ʌ], [ʊ]
80 [ʌ], [ɛ], [ɔ], [ɑ], [æ], [e], [ʊ], [u], [ɪ], [i], [o]
90 [ɔ], [u], [æ], [ɪ], [ɑ], [ʌ], [i], [e], [ɛ], [ʊ], [o]
100 [ʊ], [ɛ], [æ], [i], [ʌ], [e], [ɑ], [ɔ], [ɪ], [u], [o]

R - 70 [o], [æ], [i], [ɑ], [ɛ], [ɪ], [ʌ], [ʊ], [u], [e], [ɔ]
80 [ʊ], [i], [æ], [ɛ], [ɔ], [o], [ɑ], [u], [e], [ʌ], [ɪ]
90 [ʌ], [ɔ], [ɪ], [ɑ], [ɛ], [æ], [e], [o], [u], [i], [ʊ]
100 [o], [ʌ], [i], [ɛ], [æ], [ɪ], [ɑ], [ɔ], [e], [u], [ʊ]

B - 70 [æ], [ɔ], [i], [ɛ], [ʊ], [u], [ɑ], [e], [ɪ], [o], [ʌ]
80 [ʌ], [ʊ], [i], [ɛ], [u], [e], [ɔ], [ɑ], [ɪ], [æ], [o]
90 [e], [i], [ʌ], [æ], [ʊ], [ɛ], [ɔ], [ɑ], [ɪ], [u], [o]
100 [ɑ], [u], [æ], [e], [ɪ], [o], [ɛ], [ʌ], [ʊ], [i], [ɔ]

Random Order of Vowel Cards for Presentation

Subject (12) B L R

B - 70	[ɑ],	[ɔ],	[ɪ],	[æ],	[i],	[u],	[o],	[e],	[ɛ],	[ʌ],	[ʊ]
80	[ʌ],	[ɛ],	[ɔ],	[ɑ],	[æ],	[e],	[ʊ],	[u],	[ɪ],	[i],	[o]
90	[ɔ],	[u],	[æ],	[ɪ],	[ɑ],	[ʌ],	[i],	[e],	[ɛ],	[ʊ],	[o]
100	[ʊ],	[ɛ],	[ɔ],	[i],	[ʌ],	[e],	[ɑ],	[ɔ],	[ɪ],	[u],	[o]
L - 70	[o],	[æ],	[i],	[ɑ],	[ɛ],	[ɪ],	[ʌ],	[ʊ],	[u],	[e],	[ɔ]
80	[ʊ],	[i],	[æ],	[ɛ],	[ɔ],	[o],	[ɑ],	[u],	[e],	[ʌ],	[ɪ]
90	[ʌ],	[ɔ],	[ɪ],	[æ],	[ɛ],	[ɑ],	[e],	[o],	[u],	[i],	[ʊ]
100	[o],	[ʌ],	[i],	[æ],	[ɛ],	[ɪ],	[ɑ],	[ɔ],	[e],	[u],	[ʊ]
R - 70	[æ],	[ɔ],	[i],	[ɛ],	[ʊ],	[u],	[ɑ],	[e],	[ɪ],	[o],	[ʌ]
80	[ʌ],	[ʊ],	[o],	[ɛ],	[u],	[e],	[ɔ],	[ɪ],	[ɑ],	[æ],	[i]
90	[e],	[i],	[ʌ],	[æ],	[ʊ],	[ɛ],	[ɔ],	[ɑ],	[ɪ],	[u],	[o]
100	[ɑ],	[u],	[æ],	[e],	[ɪ],	[o],	[ɛ],	[ʌ],	[ʊ],	[i],	[ɔ]

APPENDIX C

Subject No. 1

Binaural Presentation

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	64	66	66	68	70	66	72	72	73	70	70
80 db	62	64	62	62	66	62	68	68	68	64	65
90 db	60	62	62	62	64	62	66	66	66	66	64
100 db	62	62	62	63	65	62	64	63	63	67	64

Monaural Presentation (Right)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	64	66	66	64	66	67	68	66	67	68
80 db	64	64	66	64	65	66	66	70	70	66	70
90 db	66	68	68	70	70	68	73	72	74	72	70
100 db	64	66	68	68	70	66	71	71	72	70	72

Monaural Presentation (Left)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	60	60	60	60	62	62	66	60	62	62
80 db	60	60	60	62	62	62	64	66	62	64	64
90 db	60	62	62	63	66	66	66	66	70	68	68
100 db	60	60	62	64	64	64	64	68	68	67	66

Subject No. 2

Binaural Presentation

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	62	66	67	64	64	64	70	64	66	64
80 db	66	66	68	66	66	66	69	68	66	70	69
90 db	66	66	66	68	70	66	70	70	70	68	68
100 db	68	70	66	70	71	69	76	74	74	66	72

Monaural Presentation (Right)

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	62	64	62	62	62	64	62	64	64	64
80 db	64	64	64	64	62	63	64	63	64	64	65
90 db	62	64	66	66	64	68	66	64	66	68	66
100 db	64	66	66	64	63	66	72	68	68	66	64

Monaural Presentation (Left)

Itensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	66	68	69	70	68	68	60	62	68	70	68
80 db	60	62	66	66	60	64	64	64	64	66	65
90 db	62	64	65	66	63	62	62	62	68	66	66
100 db	62	66	67	66	62	66	64	64	66	68	67

Subject No. 3

Binaural Presentation

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	70	68	70	69	64	69	72	72	66	68
80 db	61	64	70	69	68	66	72	74	72	70	68
90 db	60	66	68	69	70	64	74	76	70	70	70
100 db	62	66	65	62	67	67	72	69	68	70	70

Monaural Presentation (Right)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	60	62	60	60	60	62	62	62	62	62
80 db	68	64	64	68	66	61	66	64	66	66	65
90 db	64	64	64	64	62	64	66	66	64	66	66
100 db	62	64	64	62	64	66	66	66	66	65	66

Monaural Presentation (Left)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	58	62	62	60	59	60	64	62	62	68	62
80 db	58	62	62	62	60	62	64	62	63	62	64
90 db	58	62	62	62	62	64	64	66	64	60	64
100 db	58	62	62	61	60	62	62	62	62	64	64

Subject No. 4

Binaural Presentation

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	62	62	64	64	60	66	66	66	64	64
80 db	62	64	62	64	66	58	70	67	66	64	66
90 db	58	62	64	64	68	60	68	66	66	64	64
100 db	58	64	62	65	66	60	66	66	68	66	64

Monaural Presentation (Right)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	59	60	60	58	62	60	58	60	62	58
80 db	58	58	58	58	56	58	60	60	62	60	60
90 db	62	59	60	60	60	60	64	63	64	62	60
100 db	64	62	61	60	62	62	66	66	66	62	60

Monaural Presentation (Left)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	56	58	58	59	60	56	60	60	58	56	60
80 db	56	60	60	58	57	58	62	58	64	58	58
90 db	56	58	58	58	56	58	62	58	60	60	60
100 db	58	60	60	60	58	57	62	60	64	58	60

Subject No. 5

Binaural Presentation

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	64	64	66	64	66	66	64	64	66	72
80 db	62	66	66	72	68	66	70	70	68	69	68
90 db	62	66	66	70	68	66	70	68	70	68	70
100 db	64	66	66	72	68	70	68	70	70	68	68

Monaural Presentation (Right)

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	58	60	62	64	62	62	62	62	62	62	62
80 db	58	62	60	64	62	60	62	62	64	60	62
90 db	60	64	62	66	62	60	64	64	64	62	64
100 db	60	62	64	64	64	64	62	64	65	62	66

Monaural Presentation (Left)

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	64	64	66	62	60	66	62	64	63	64
80 db	60	65	64	64	62	60	64	64	63	64	62
90 db	60	64	62	64	62	62	64	62	63	62	64
100 db	60	62	62	66	62	60	63	64	64	62	62

Subject No. 6

Binaural Presentation

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	62	69	72	64	65	72	66	68	62	62
80 db	60	58	68	70	56	58	60	60	60	58	56
90 db	54	66	56	58	56	56	56	66	53	62	58
100 db	54	56	54	56	58	56	56	58	64	54	55

Monaural Presentation (Right)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	54	62	56	56	54	56	56	58	58	58	56
80 db	58	54	51	58	58	58	54	60	58	56	56
90 db	56	56	56	56	56	58	58	56	54	58	58
100 db	57	58	56	56	58	58	58	56	60	59	56

Monaural Presentation (Left)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	54	56	54	58	54	58	54	56	56	58	58
80 db	56	56	54	54	56	56	52	56	56	56	56
90 db	54	55	54	52	54	58	56	54	54	54	56
100 db	54	54	56	56	58	59	56	56	56	54	54

Subject No. 7

Binaural Presentation

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	66	70	68	70	70	66	68	68	71	70	67
80 db	68	70	70	70	72	70	70	70	74	74	70
90 db	68	72	72	74	72	70	75	74	76	74	74
100 db	68	72	72	76	76	70	76	76	76	76	76

Monaural Presentation (Right)

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	66	68	66	68	70	68	66	68	70	70	68
80 db	64	68	68	68	67	68	66	68	70	69	68
90 db	68	68	68	68	72	66	70	68	72	72	68
100 db	68	68	68	68	68	66	68	70	70	70	68

Monaural Presentation (Left)

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	64	66	64	64	64	66	62	64	66	64
80 db	62	64	64	62	62	60	63	64	66	64	64
90 db	62	64	64	64	64	62	64	66	66	64	66
100 db	64	65	66	66	65	65	66	68	68	66	64

Subject No. 8

Binaural Presentation

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	62	66	64	66	62	66	68	68	68	68
80 db	66	68	68	72	68	64	66	72	72	70	68
90 db	68	74	72	72	74	68	70	76	74	72	70
100 db	74	76	72	76	76	74	76	76	78	76	76

Monaural Presentation (Right)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	58	62	64	62	62	60	66	68	66	66	60
80 db	62	62	68	64	66	62	66	64	67	68	66
90 db	60	64	64	66	65	60	64	66	66	66	64
100 db	62	64	68	68	64	62	66	66	66	68	64

Monaural Presentation (Left)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	66	66	66	70	66	66	68	68	68	68
80 db	64	66	64	68	68	68	66	66	66	70	68
90 db	59	64	65	66	66	61	64	64	66	68	60
100 db	60	64	64	66	66	64	66	61	66	66	64

Subject No. 9

Binaural Presentation

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	64	68	66	72	72	66	72	70	74	70	70
80 db	64	68	70	70	68	64	72	72	68	70	68
90 db	62	68	68	68	68	62	68	68	68	68	68
100 db	64	65	65	66	66	60	70	64	68	66	66

Monaural Presentation (Right)

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	66	62	66	65	64	64	66	64	68	62
80 db	64	66	66	60	66	60	67	64	68	66	66
90 db	62	64	64	66	66	62	68	64	64	68	66
100 db	59	66	62	66	62	68	62	60	60	68	62

Monaural Presentation (Left)

Intensities	[i]	[I]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	60	60	64	61	58	62	60	66	62	60
80 db	60	64	63	62	64	60	64	66	66	66	64
90 db	60	66	64	66	62	60	66	68	60	64	63
100 db	60	64	62	64	61	58	62	64	64	64	62

Subject No. 10

Binaural Presentation

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	58	60	60	60	60	61	60	60	62	62	60
80 db	60	60	60	60	60	62	60	60	62	64	60
90 db	58	58	60	60	63	61	60	60	60	60	60
100 db	60	60	64	61	60	64	58	62	58	62	62

Monaural Presentation (Right)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	60	60	60	60	62	58	56	58	60	58
80 db	58	60	58	56	56	60	60	58	56	58	57
90 db	58	60	58	58	55	62	58	56	58	60	60
100 db	60	60	58	58	58	62	58	58	58	60	60

Monaural Presentation (Left)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	59	60	59	59	60	60	60	58	60	60	59
80 db	57	62	60	58	58	60	60	58	60	56	60
90 db	58	56	55	56	56	58	56	56	58	60	57
100 db	56	60	60	58	60	60	60	58	60	58	60

Subject No. 11

Binaural Presentation

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	62	64	65	66	60	66	68	68	64	64
80 db	62	62	64	66	66	62	67	68	66	66	64
90 db	60	66	66	66	66	63	67	66	68	66	66
100 db	64	66	67	68	68	62	68	70	70	68	66

Monaural Presentation (Right)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	60	62	62	64	64	60	64	66	64	68	64
80 db	58	62	62	66	64	60	66	66	65	64	64
90 db	60	62	64	64	64	60	62	66	66	64	62
100 db	60	62	64	64	64	62	66	64	66	64	64

Monaural Presentation (Left)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	66	66	68	70	64	68	72	72	68	66
80 db	58	62	64	66	66	64	66	67	66	66	66
90 db	62	66	64	66	66	62	68	68	66	66	66
100 db	62	64	64	66	64	62	66	66	66	64	68

Subject No. 12

Binaural Presentation

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	64	68	70	64	63	66	64	70	68	68	66
80 db	66	68	70	68	67	68	66	70	70	70	66
90 db	68	66	74	72	68	68	70	72	72	72	68
100 db	68	70	74	72	73	72	72	76	72	74	70

Monaural Presentation (Right)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	62	62	64	60	62	64	62	64	62	64	64
80 db	62	62	66	62	62	66	64	66	66	66	64
90 db	62	64	65	64	64	64	62	64	64	68	64
100 db	64	62	64	66	64	66	68	64	66	68	64

Monaural Presentation (Left)

Intensities	[i]	[ɪ]	[e]	[ɛ]	[æ]	[u]	[ʌ]	[ɑ]	[ɔ]	[o]	[ʊ]
70 db	64	62	64	66	62	62	62	64	64	64	64
80 db	66	62	64	66	63	64	64	64	64	66	64
90 db	62	62	64	64	64	64	64	64	64	66	64
100 db	64	62	68	64	62	64	64	64	68	64	64

BIBLIOGRAPHY

Books

Dixon, Wilfrid J., and Massey, Frank J., Jr. Introduction to Statistical Analysis. New York: McGraw-Hill Book Company, Inc., 1958.

Heller, Morris F., Anderman, J., and Singer, Ellis E. Functional Otology: The Practice of Audiology. New York: Springer Publishing Co., Inc., 1955.

Newby, Hayes A. Audiology Principles and Practice. New York: Appleton-Century-Crofts, Inc., 1958.

Articles and Periodicals

Black, John W. "Natural Frequency, Duration, and Intensity of Vowels in Reading," Journal of Speech and Hearing Disorders, XIV (September, 1949).

Black, John W. (ed.). "Studies in Speech Intelligibility," Speech Monographs, XIII (Number 2, 1946).

Dreher, John J. and O'Neill, John J. "Effects of Ambient Noise on Speaker Intelligibility of Words and Phrases," Laryngoscope, LXVIII, Part 1 (1958).

Fairbanks, G., House, A. S., and Steven, L. "An Experimental Study of Vowel Intensities," Journal Acoustical Society of America, XXII (July, 1950).

Grove, W. E. "Simulation of Deafness," Annals of Otology, Rhinology, and Laryngology, LII (September, 1943).

Hanley, T. D., and Steer, M. "Effect of Level of Distracting Noise Upon Speaking Rate, Duration, and Intensity," Journal of Speech and Hearing Disorders, XIV (December, 1949).

Korn, T. S. "Effect of Psychological Feedback on Conversational Noise Reduction in Rooms," Journal Acoustical Society of America, XXVI (September, 1954).

Sacia, C. F., and Beck, C. J. "The Power of Fundamental Speech Sounds," Bell System Technical Journal, V (July, 1926).

Stevens, Kenneth N., and House, Arthur S. "An Acoustical Theory of Vowel Production and Some of Its Implications," Journal of Speech and Hearing Research, IV (December, 1961).

Taylor, Glenn J. "An Experimental Study of Tests for the Detection of Auditory Malingering," Journal of Speech and Hearing Disorders, XIV (March, 1949).

Unpublished Material

Waldron, D. L. "The Lombard Voice Reflex Test: An Experimental Study." Unpublished Doctoral dissertation, Department of Speech, Stanford University, 1960.