MAY, BETTY JO WHITTEN. A Phonetic Analysis and Comparison of Nineteen Consonant Sounds as they appear in the Speech of Normal Hearing and Hard-of-hearing Children. (1969) Directed by: Dr. Lawrence M. Vanella. pp. 90

The objectives of this study were to compare the speech patterns of normal hearing and hard-of-hearing children in order to further describe the relationship of these two groups; to survey the literature to determine group comparisons already established; to provide statements which would further clarify the relationship; and to report these statements for use in the field of speech and hearing pathology. A total of one hundred thirty-four subjects were used in the study. An audiogram and speech analysis were secured on each subject. Subjects were then divided into five groups: Normal hearing; slight hard-of-hearing; moderate hard-of-hearing; educationally deaf; and profoundly deaf. Sound graphs were formed which revealed the percentage of subjects in each group having a given sound defective. These sound graphs were grouped according to site of placement and manner of formation.

In addition, computer analysis was used to determine the correlation coefficients of 23 variables in the four groups with the hard-of-hearing subjects. As a result of the Fortran program output, new sound graphs were formed, suggesting there may be another consonant grouping in addition to site of placement, manner of formation, and surd-sonant phonemes. Using the high correlation groups, a minimum number of sounds was selected which appears sufficient for an articulation test for hard-of-hearing children. The sounds chosen were [p k θ l g sʃ] because each of the new correlation groups contains at least one of these sounds.

Scatter diagrams with regression lines were presented which described the relationship between a phoneme and hearing loss. Finally, two tables were presented: One which showed the percentage of male and female subjects who have hearing loss; the other lists the analyzed sounds in order of difficulty for each of the five groups.

Results of this study were compared to the results of earlier studies in the field of audiology. Implications of the study were revealed, including areas for further research.

A PHONETIC ANALYSIS AND COMPARISON OF NINETEEN CONSONANT SOUNDS AS THEY APPEAR IN THE SPEECH OF NORMAL HEARING AND HARD-OF-HEARING CHILDREN

by

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APPROVAL SHEET

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CHAPTER I

INTRODUCTION

Deafness and its relationship to speech has been recognized for centuries. Aristotle[1] mentioned in his writings that when a person is deaf, dumbness will of necessity be mutually coexistent. This incorrect cause-and-effect relationship of deafness to dumbness caused educational progress for the deaf to be delayed for literally hundreds of years. Di Carlo[2] provides an historical account of the development of audiology as a science. Studying some of these historical resources reveals that statements regarding the speech-hearing relationship have too often taken the form of opinion rather than research.

The intent of this paper is to describe a part of the speech-hearing relationship. Specific information regarding speech and hearing should be helpful to pathologists and audiologists in the clinic, classroom, and laboratory. A descriptive study follows of nineteen consonant phonemes as they appear in the speech of normal hearing, hard-of-hearing, and deaf children. Chapter II reports the procedures used in testing the 134 children used for the study. Children tested were divided into five groups (according to the

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[1] Louis Di Carlo, The Deaf (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1965), p. 12.

[2] Ibid., 12-41.

amount of hearing loss) and the speech patterns of these groups were compared. Chapter III reports results of this comparison, including sound-graphs for each phoneme and the correlation coefficients and mean and standard deviations of the variable pairs. Chapter IV includes a discussion of the results. The significance of the study will be interpreted from the point of view of speech and hearing personnel.

Various approaches have been used to describe the speech-hearing relationship. Although this paper concentrates on the individual phoneme and its relationship to hearing loss, analyzing individual sounds was not the earliest research method. During the last thirty-five years significant observations have been made about the deaf and hard-of-hearing, which make the detailed statistics of this paper more meaningful. An historical account follows describing the research path from the broadest speech-hearing relationship to the more specific one of this paper.

Included in ths historical resumé will be the development of audiology as a science; the improvement in diagnostic techniques; educational considerations of the deaf and hard-of-hearing; comparisons in language ability and intelligibility scores; speech sound discrimination studies; a description of the phoneme-hearing relationship as it appears in studies similar to the one of this paper.

The Science of Audiology Appears

Before World War II, the diagnosis and treatment of those with hearing loss was done by one of two professionals: the speech pathologist, who dealt primarily with disorders of oral language; or the otologist who treated individuals with diseases of the ear or disorders of the peripheral mechanism of hearing. The speech therapist usually assumed most of the responsibility for the diagnosis and treatment of the hard-of-hearing.

These two professions, by working harmoniously, developed a new area of specialization, audiology. This term first came into general use in 1945 when Raymond Carhart,[1] a speech pathologist recruited for army aural rehabilitation, used it in a professional article. The term audiology designates the profession, rather than the commercial worker in the field.

Improvement in Diagnostic Techniques

Newby[2] describes the watch-tick test, wherein the tester puts a watch near the patient's ear. As the watch was moved away, the patient reported when he no longer heard the tick. The normal person no longer heard the tick at a distance of thirty inches. If the patient no longer heard at a distance of twelve inches,

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[1] Raymond Carhart and George Shambaugh, "Contributions of Audiology to Fenestration Surgery," American Medical Association Archives of Otolaryngology, LIV (December, 1951), 611.

[2] Hayes Newby, Audiology (New York: Appleton-Century-Crofts, 1959), pp. 58-65.

the hearing loss was reported to be 12/30. Another test described is the Rinne tuning fork test, which originated in Austria in the nineteenth century. Conductive and perceptive hearing losses were diagnosed by placing the fork in vibration and holding it to the auricle. The patient reported the moment he no longer heard the fork's vibration. The tester immediately placed the fork on the mastoid process. If the patient could hear the vibration, the test was Rinne negative, indicating a conductive lesion. A Rinne positive would act in reverse and the loss would be sensori-neural.

In 1936 Kerridge[1] reported the normal hearing child could hear words spoken twenty feet from the teacher's desk; the partially deaf child could hear between twenty and two feet from the desk; and if the child could hear from a distance of two feet or less, he would be classified as deaf.

Today the clinician has refined his diagnostic procedures so that the audiogram is a familiar sight among speech, medical and school personnel. Attempts are also being made to understand the numerous factors relating to deafness. One way of describing characteristics of the deaf and hard-of-hearing is to compare them with normal hearing persons. Some of those studies will be described.

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[1] Phyllis Kerridge, "Hearing and Speech and Deaf Children," Proceedings of the Royal Society of Medicine, XXX (May, 1937), 1494-1511.

Intellectual, Psychological, Educational Comparisons

Sprunt[1] reporting on forty-six hard-of-hearing children, found that although there was no significant I.Q. difference in the two groups (normal and hard-of-hearing), there was educational retardation. Farrant[2] reports that although children do score lower on most standardized intelligence tests, their lack of communicative ability is the factor which determines their low score and not an innate lack of intelligence.

A study by Reynolds revealed that children with minimal hearing loss (below 30 db.) are not handicapped in their adjustment to school. He states, "It would seem that there are other problems in the child's environment which far surpass in importance any minimal hearing loss."[3] Rutledge[4] reports there are no differences in aspiration levels of deaf and normal hearing children, except in areas where the handicap is actually a factor. O'Connor[5] states

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[1] Julie Sprunt, "Auditory Deficiency and Academic Achievement," Journal of Speech and Hearing Disorders, XIV (March, 1949) 26-32.

[2] Roland Farrant, "The Intellective Abilities of Deaf and Hearing Children Compared by Factor Analysis," American Annals of the Deaf, CIX (March, 1964), 306-325.

[3] Lyle Reynolds, "The School Adjustment of Children with Minimal Hearing Loss," Journal of Speech and Hearing Disorders, XIX (September, 1954), 375-380.

[4] Louis Rutledge, "Aspiration Levels of Deaf Children as Compared with Hearing Children," Journal of Speech and Hearing Disorders, XX (September, 1954), 380-390.

[5] Clarence O'Connor, "The Integration of the Deaf in Schools for the Normally Hearing," American Annals of the Deaf, CVI (September, 1961), 232.

that deaf children may successfully integrate the hearing classroom if they have one ability above all others, that is, the ability to communicate.

With general agreement that increasing intelligibility is one of the most desirable attainments for deaf and hard-of-hearing students, literature is prolific in the proper speech teaching methods. Hudgins[1] does not recommend teaching the exact production of each individual phoneme, since the rhythm of speech is as important to intelligibility as correct sound production. Numbers[2] reports that some teaching methods actually encourage defective sound production and he describes the hybrid consonant sounds being taught in schools.

Comparisons in Language Ability and Intelligibility

Speech deviations are present in the deaf. "Dummy" and "mute" are terms still in use. Kerridge states, "There is a peculiarity of timbre about taught 'deaf speech' which defies description."[3]

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[1] Clarence Hudgins, "Speech Breathing and Speech Intelligibility," The Volta Review, XLVII (November, 1946), 642-644.

[2] Fred Numbers, "The Versatile Consonant," The Volta Review, XLVII (December, 1946), 638-640.

[3] Kerridge, "Hearing and Speech," p. 1507.

Hudgins, however, refutes the idea of deaf speech, reporting:

> The speech of deaf subjects presents such wide variabilities in all the quantitative aspects studied that it becomes impossible to formulate a standard deaf speech. Even if it were possible to do so, the value of such a standard would be nill since it is the purpose of any progressive oral program to develop normal speech and language in the deaf. Therefore, the speech of normal people is the only legitimate standard with which it is feasible to compare the speech of the deaf.[1]

Language ability of normal, deaf, and hard-of-hearing has been measured by Brannon.[2] This report revealed that subjects with a significant hearing impairment (75db. - 100 db.) have less use of adverbs, pronouns and auxiliaries. In an earlier study of language assessment of normal, deaf, and hard-of-hearing, Brannon and Murray[3] reported the hard-of-hearing group resembled the normal control group in number of errors of addition, omission, substitution and word order. Deaf scored significantly lower.

Hudgins[4] has developed a method of appraising the speech of the deaf. Bodycomb[5] reports with dismay that visitors in a school

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[1] Clarence Hudgins, "A Comparative Study of Speech Coordination of Deaf and Normal Subjects," Journal of Genetic Psychology, LIV (January, 1934), 3.

[2] John Brannon, "Linguistic Word Classes in the Spoken Language of Normal, Hard-of-Hearing, and Deaf Children," Journal of Speech and Hearing Research, IX (December, 1966), 604-629.

[3] John Brannon and Thomas Murray, "The Spoken Syntax of Normal, Hard-of-hearing and Deaf Children," Journal of Speech and Hearing Research, IX (December, 1966), 604-629.

[4] Clarence Hudgins, "A Method of Appraising the Speech of the Deaf," The Volta Review, LI (October, 1949), 597-601.

[5] Margaret Bodycomb, "Speech of the Deaf and of the Normal Speaker," The Volta Review, XLVII (November, 1946), 637-641.

for the deaf often understand the imperfect speech of the newly arrived hard-of-hearing pupil better than the careful utterances of the totally deaf. Bodycomb reports there is no individual personality expressed in the speech of the deaf due to the excessive concern with the mechanics of speech.

Comparisons in Speech Sound Discrimination

Speech sound discrimination ability has been analyzed and reported on with conflicting results. Hall[1] reports there is no difference in the discrimination ability of the speech defective and the normal speaker. The sounds most often missed for both groups in discrimination tests were the sounds [s z ʃ tʃ dʒ]. Hansen[2] generally substantiated Hall's findings in his 1944 report by giving three tests of sound discrimination to three groups of normal hearing children: (1) untrained speech defectives with functional articulatory defects; (2) normal speakers; (3) trained defectives with functional articulatory defects. There was no difference in the discrimination ability of the three groups. Travis and Rasmus[3] report that speech defectives do not consistently miss any particular pair of sounds more frequently than normals. A further

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[1] M. E. Hall, "Auditory Factors in Functional Articulatory Speech Defects," Journal of Experimental Education, VII (March, 1938), 110-132.

[2] Burrell Hansen, "The Application of Sound Discrimination Tests to Functional Articulatory Defectives with Normal Hearing," Journal of Speech Disorders, IX (December, 1944), 347-355.

[3] Lee Travis and Paul Rasmus, "Speech Sound Discrimination of Cases with Functional Disorders of Articulation," Quarterly Journal of Speech, XVII (October, 1931), 217-226.

look into the discrimination ability of those with deafness was made by Plummer. The discrimination tests of those children revealed they had no appreciable difficulty in discriminating

> . . . between consonants which heretofore have been said to depend highly upon sensitivity to high frequency sound. High frequency sound is a misnomer if used to indicate that these sounds depend primarily on high frequencies for their discrimination. The ability to discriminate between these sounds appears to be chiefly influenced by the amount of hearing loss and the extent of the loss.[1]

The Speech-Hearing Relationship Described

In 1939 Harmes and Malone[2] reported that loss of hearing acuity during the period of speech formation is a cause of stammering. At about the same time Newhart[3] concluded that sub-normal hearing causes a very substantial proportion of speech defects. Hudgins[4] isolated some abnormalities in the speech of the deaf. Some of these are: extremely slow and labored speech accompanied by high chest pressure and uttered with an excessive amount of breath; prolongation of vowels; consonant distortion with the addition of

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[1] Robert Plummer, "High Frequency Deafness and Discrimination of High Frequency Consonants," Journal of Speech Disorders, VII, (September, 1943), 373-381.

[2] Arline Harmes and J. Y. Malone, "Hearing Acuity and Stammering," Annals of Otology, Rhinology, and Laryngology, XLVII (November, 1939), 658-662.

[3] Horace Newhart, "Hearing Deficiencies in Relation to Speech Defects," Laryngoscope, XLVII (January, 1938), 129-137.

[4] Hudgins, "A Comparative Study," 12.

extra syllables. Residual hearing is also an important factor in deaf speech. Pitch differences between normal and hard-of-hearing are described by Voelker[1] and Penn.[2]

Although consonant sounds were used as a basis for this study, Vowel sounds have also been under examination. Studies by Penn,[3] Hudgins[4] or Angelocci[5] report their observations on the vowel production of deaf and hard-of-hearing and normal children.

Descriptive Studies of the Phoneme-Hearing Relationship

Kerridge's[6] lecture to the Royal Society of Medicine in 1936 described specific areas where speech and hearing are related. The inability to copy that which is not heard applies to speech components. The most common example is heard in the frequent omission of [s] and [ʃ] from the speech of moderately deaf children

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[1] C. H. Voelker quoted by C. W. Hudgins and Fred Numbers, "An Investigation of Speech Intelligibility of the Speech of the Deaf," Genetic Psychology Monographs, XXV-XXVI, (January, 1942), 289-395.

[2] Jacques Penn, "Voice and Speech Patterns of the Hard-of-Hearing," Acta Oto-Laryngologica, (Supplementum 124, 1955), 1-69.

[3] Ibid., 33-69.

[4] Hudgins and Numbers, "An Investigation of Speech Intelligibility," 289-375.

[5] Angelo Angelocci, George Kopp, Antony Holbrook, "The Vowel Formants of Deaf and Normal-Hearing Eleven-to-Fourteen-Year-Old Boys," Journal of Speech and Hearing Disorders, XXIX, (May, 1964), 156-170.

[6] Kerridge, "Hearing and Speech."

with normally developed powers of conversation. Kerridge reported: At 30 db. or less, normal natural speech was the rule; between 30 db. and 50 db., speech was natural in tone but defective in articulation; thereafter, as hearing loss increased, the percentage of fair or poor speech increased greatly. In this study teachers rated the speech of the children as normal, good, fair, poor. As nearly as can be determined, Kerridge concurred with these diagnoses by listening to the speech patterns of the children on a gramophone record. Kerridge reports on general areas of proficiency, but he does not specifically describe the diagnostic terms of natural, good, fair, poor.

Harriet Green[1] in her 1940 Master's thesis reported that hard-of-hearing children omit final consonants, confuse surd-sonant sounds, and most often substitute other sounds for the [t k s r θ l]. The most prevalent defect was lisping. She compiled these results on all children tested with hearing loss from 20 db. - 70 db.

In 1942 Hudgins and Numbers[2] evaluated quantitatively the intelligibility of the speech of 192 deaf pupils. Consonant errors were divided into several categories. Among them were confusion

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[1] Harriet Green, "A Study of Speech of the Hard-of-Hearing in the New York City Public Schools in Order of Frequency," (unpublished Master's thesis, Brooklyn College, 1940), 1-46.

[2] Hudgins and Numbers, "An Investigation of Speech Intelligibility."

of the surd-sonant sounds; substitution of one sound for another; errors involving velum control; non-function of the arresting consonant; non-function of the releasing consonant. Articulation errors were analyzed according to difficulty of individual phonemes; according to the degree of hearing loss; and according to age. These results will be discussed and compared with those of this paper in Chapter IV.

Mangum[1] in 1961 compiled the percentage of consonant errors used by the educationally deaf and the profoundly deaf. Penn[2] gave speech evaluations to two hundred veterans who were hard-of-hearing. He reported that the nature of the hearing loss is associated with the nature of voice and speech deviations and he lists the particular phoneme deviations which were most prevalent.

This comparative research continues to the present. Huntington and Sholes[3] reveal the direction of current research by reporting results of an electromyographic study of consonant articulation in two hearing impaired and two normal adult speakers.

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[1] Kenneth Mangum, "Speech Improvement Through Articulation Testing," American Annals of the Deaf, LVI (August, 1961), 391-396.

[2] Jacques Penn, "Voice and Speech Patterns of the Hard-of-Hearing," Acta Oto-Laryngologica, (Supplementum 124, 1955), 1-69.

[3] Dorothy Huntington, Katherine Harris, George Sholes, "An Electromyographic Study of Consonant Articulation in Hearing-Impaired and Normal Speakers," Journal of Speech and Hearing Research, XI (March, 1968), 147-158.

Conclusion

The speech-hearing relationship has been studied from various points of view. Descriptive, historical and experimental studies have added to our knowledge in this field. The remaining chapters of this thesis intend to further explore this relationship in order to make a factual, not speculative, contribution to the field of speech and hearing. In addition, the articles by Kerridge, Penn, Green, and Hudgins and Numbers will be discussed in more detail in Chapter IV.

CHAPTER II

PROCEDURE

Procedures were utilized in this study to obtain speech analyses and pure tone audiograms on several selected groups of children: normal hearing; hard-of-hearing; and deaf or deafened children. One hundred thirty-three children, ages 6-17, were used in this study. The children were (1) referrals from public schools who had been referred to the Virginia Hearing Foundation Speech and Hearing Clinics and (2) students from the Virginia School for the Deaf.

This chapter will describe the nature of the speech and hearing clinics. Methods for articulation testing and securing of audiograms will be discussed. Psychological and physiological considerations will be mentioned. After the data collection process has been described the method of data analysis will conclude the chapter.

Selection of Subjects

Public School Subjects. The public school subjects consisted of fifty-five normal hearing children with speech defects and thirty hard-of-hearing children with speech defects. The children had been referred to one of two speech and hearing clinics: one in Brookneal, Virginia; the other in Madison, Virginia. These clinics were requested by the community and conducted by the Virginia Hearing Foundation.

The Virginia Hearing Foundation is a private non-profit organization dedicated to early and accurate diagnosis of hearing disorders. The clinics for this purpose were held in public school facilities. A referral method similar to the one described by Irwin[1] was used. Advance publicity on radio and in newspapers informed parents, teachers and community social workers of the nature of the clinic. Although most children were teacher referred, a few arrived with parents or community personnel.

The field speech and hearing clinics were staffed by students in speech pathology and audiology at the University of Virginia in Charlottesville. Coordinator of Field Services of the Virginia Hearing Foundation and director of the clinic held the A.S.H.A Basic Certificate in Speech.

Deafened and Deaf Subjects. The Virginia School for the Deaf in Staunton, Virginia, provided the deaf subjects. The clinic director, after conferring with school personnel, was given access to files on the children. The school also provided the audiograms for each subject.

Tests, Instruments, and Procedures

The Articulation Test. The Bryngelson-Glaspey Picture Articulation Test[2] was administered to each subject. Other picture

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[1] Ruth Irwin, Speech and Hearing Therapy, (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1956), pp. 31-41.

[2] Bryng Bryngelson and Ester Glaspey, Speech Improvement Cards (Chicago: Scott-Foresman Company, 1962).

cards testing consonant sounds were added to the test. Test words used for each sound and the corresponding phonetic symbol tested are listed in Appendix A.

A brief period was spent establishing rapport with each child. The older children were told, in effect, "I know this activity appears simple for you, but I am very much interested in how you say these words. As you say them, I will probably write down what you say." The tester then presented the picture cards and transcribed the results on a test sheet (Appendix B) utilizing the International Phonetic Alphabet. An interpretation of the transcription appears on the sample test sheet in Appendix B. The clinic director and author of this paper recorded the phonetic transcription. The author felt that maximum cooperation was obtained from the subjects.

Audiometric Tests. Each public school subject was examined on a Maico MA-11 audiometer recently (within one year) calibrated by the American Standards Association. A pure tone air conduction sweep check was administered to each subject at the following frequencies: 256, 512, 2048, 4096, and 8192 cps. Intensity was held constant at 15 db. Subjects who failed to respond correctly in the sweep-frequency method described by Davis[1] were given audiometric, pure tone threshold tests using the method described by

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[1] Hallowell Davis, <u>Hearing and Deafness, A Guide for Laymen</u> (New York: Rinehart and Company, 1955), p. 357.

Heller.[1] An example of the audiogram used was included on the test sheet (Appendix B).

Physiological and Psychological Considerations. The public school children were observed for obvious organicity of lips, teeth, tongue and palate. Case history information was obtained from parents, school personnel or community social workers. Psychological evaluations provided by the school gave an estimate of each child's intelligence. Public school children suspected of mental retardation, severe emotional instability, or organic impairment of the speech mechanism were not included in the sample.

Physiological and psychological considerations for the deaf were not the same as those for the public school children. Most of the subjects from the school for the deaf had intelligence quotients below normal. Students evaluated by school personnel as being aphasic or students appearing to be severely mentally retarded were not included in the study. Other subjects were omitted by the examiner when they appeared not to know the names of the test pictures.

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[1] Morris Heller, Functional Otology, The Practice of Audiology (New York: Spring Publishing Company, 1955), pp. 55-58.

Compilation of the Data

Examination of the audiometric data revealed the subjects could be divided into five groups.

Group I	Fifty-five children with functional speech defects, normal hearing, and attending public school.
Group II	Eighteen children with speech defects, slight hearing loss (20 db. - 40 db.), attending public school.
Group III	Twelve children with speech defects, moderate to severe hearing loss (40 db. - 70 db.) attending public school.
Group IV	Thirty-three children with speech defects, educationally deaf[1] (50 db. - 80 db.) attending a school for the deaf.
Group V	Fifteen children with speech defects, severely deaf or deafened (80 db. - 100 db.) attending a school for the deaf.

Individual subjects in each group were listed showing amounts of hearing loss in db. (bilateral) and the phonetic analysis of his speech sample. In addition each child was scored according to the severity of that sound. If the sound was not defective, the score was zero. For each sound defective in one position, the score was one; for each sound defective in two positions the score was 2; sounds defective in three positions received a score of 4. These scores were recorded on a data sheet from which all further statistics were compiled.

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[1] Kenneth Mangum uses the term "educationally deaf" to describe children who have some residual hearing but must be placed in schools for the hearing handicapped; see, e.g., his article "Speech Improvement Through Articulation Testing," (American Annals of the Deaf, CVI, 1961).

Methods of Data Analysis

Forming Sound Graphs. For each of the nineteen sounds a graph was obtained by computing for each group the percentage with that sound defective. The plotted points were interconnected with line segments. These sound graphs were then partitioned for the following consonant categories: (1) <u>The manner of formation</u>. This included the plosives [p b t k d g] in one set; the glides [l r] in a second set; the fricatives [f v θ ð]; sibilants [s z ʃ tʃ dʒ]; and nasal sounds [m n] each in a set. (2) <u>The site of articulation</u>. These sets include the bi-labial sounds [m b p]; labio-dental [f v]; lingua-alveolar [t d n l s z r tʃ dʒ]; lingua-dental[θð]; and lingua-velar [k g]. The sound-graphs were, in addition, partitioned according to graph similarities.

Method of Computer Analysis. Each hard-of-hearing or deaf subject had twenty-three test scores or variables. Nineteen variables were the consonant sounds. The remaining variables represented total errors, and the high frequency loss, low frequency loss and speech range loss. The test scores for each subject were punched on an IBM card. The data deck of seventy-eight cards was used as input to a correlation program. The correlation program was written in Fortran Language and was run on an IBM 1620 computer. This program compared each of the 231 variable pairs (x,y) and computed for each pair: (a) the mean and standard deviation of x; (b) the mean and standard deviation of y; (c) the correlation coefficient.

The output of the program was a printed list of these computations. In addition these computations appeared as punched cards in an output deck. For ease of analysis the correlation coefficients were rewritten in the form of a 23 x 23 matrix, Appendix C.

Limitations. Several limiting factors were observed while securing raw data and are noted below.

(1) Test samples for Groups II, III, and V are small. This would consistently be the case for Groups II and III in clinics such as the one described, for children with hearing loss have the invisible handicap so often overlooked by parents and teachers. In Group V the sample will be small as relatively few children have an 80 db. hearing loss.

(2) Only nineteen consonant sounds were analyzed in the study. They are: [r l n m d g p b t k z v ʒ s ʃ f θ dʒ tʃ]. Several consonant sounds were omitted from analysis because the test pictures caused confusion and the examiner had to say the word for the subject to repeat.

(3) The audiograms secured in the public school environment were not as accurate as those of the sound treated room at the school for the deaf. It was felt, however, they were accurate enough to serve as a basis for comparison.

(4) The administering of simple picture tests to the older children may have had some effect on verbal response. Some subjects appeared self-conscious at having to repeat names of childish objects.

(5) All subjects had not had equal opportunity for speech training. None of the public school children had had previous speech therapy. All of the children at the school for the deaf had experienced intensive speech training. The nature of their speech program was not explored. Sign language was, in every instance, the primary means of communication.

(6) When dealing with correlation coefficients, there is the possibility that the significant correlation arrived at does not represent the correlation for the total population. The method of scoring determined by the examiner could effect the accuracy of the computed correlation.

CHAPTER III

METHODS OF DATA COMPILATION AND ANALYSIS

This chapter presents the methods used to analyze data. The formation of sound graphs is described. In addition there is an explanation of the statistical methods used to form a regression line and to arrive at correlation coefficients. The formula for the regression line will be presented with definitions and notations.

After the methods of analysis have been described, the use of these methods will be illustrated in several areas. (1) Some general observations will be made which result from the study of the matrix of the correlation coefficients. (2) Scatter diagrams will be presented for several of the sounds. Using the formula, a regression line will be formed for each diagram. This displays the linear relationship that exists between pairs of variables. (3) Analysis is made of consonant groupings of site of placement and manner of articulation. These groups described by Heller and others are generally accepted to be natural consonant groupings, where all consonants in the group have some property in common. Sound graphs of these groups will be presented to determine if these groups are graphically similar. Further, the correlation coefficients will be used to measure the extent that sounds within each group are related to the subject's ability to make the sounds.

(4) High correlation groups will be formed. Using the correlation coefficients a new grouping of consonant sounds will be presented which, heretofore, have not been mentioned in professional literature. In addition, sound graphs for each of these groups will be formed to display pattern similarity. It will be observed that the graph similarities improve as the correlation of grouped sounds to hearing loss improves. (5) In addition, two tables will be presented; one which computes the percentage of males and females who have hearing loss; the second lists the sounds in order of difficulty as they appear in each of the five groups.

The chapter concludes with the presentation of an articulation test which utilizes only seven phonemes. A minimum number of sounds was selected from the high correlation groups. Based on their high correlation with the other sounds, those selected should be sufficient in the testing of articulation of subjects who are hard-of-hearing.

Methods of Analysis

Sound graphs are described. For each of the selected nineteen consonant sounds, a sound graph was obtained by computing for each group the percentage of children with that sound defective. The vertical axis represents the five groups selected for comparison: normal hearing speech defectives (N); slight hard-of-hearing speech defectives attending public school (S); moderate hard-of-hearing speech defectives attending public school (M); the educationally deaf attending the school for the deaf (E.D.); and the profoundly deaf attending a school for the deaf (P.D.). The horizontal axis represents the percentage of that group which had that sound defective. The plotted points were interconnected with line segments thus forming a sound graph. Each graph represents a different phoneme.

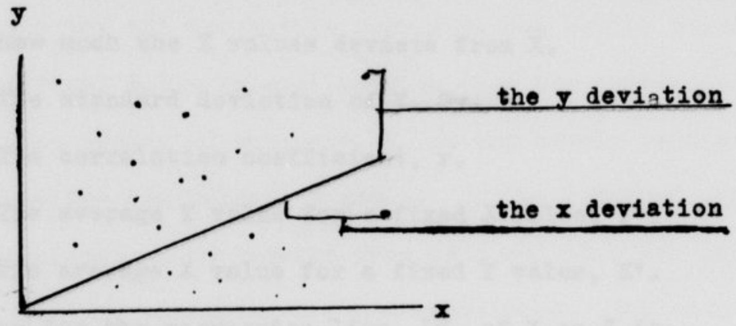
Regression lines described. A correlation problem considers the variation of the measurements or scores of two variables. A picture or graph of these measurements can be formed by letting the two coordinate axes correspond to the two variables. A point is plotted for each person in the sample population. The coordinates for each point are the measured values of the two variables for each person. This graph is called a <u>scatter diagram</u>.

The variation of the measurements may be visualized by the variation of the points in the scatter diagram. The statistical procedure is to assume a linear relationship exists between the two variables; to determine the equation of a line, called a <u>regression line</u>; and then measure the extent that the points of the scatter diagram deviate from this line. If the points are close to the regression line the variables are <u>highly correlated</u>. If no correlation exists the variables are <u>independent</u>. In this case, the points will be scattered away from the regression line.

The correlation coefficient. A statistical value called the correlation coefficient is used to measure the extent of correlation between the variables. The computed value will be between +1 and -1. If the correlation coefficient is zero the variables

are independent. The greater the number deviates from zero, the higher the correlation. A perfect correlation exists if the number is either +1 or -1.

An Example. The two variables under consideration are denoted by x and y. Consider the scatter diagram and line:



The distance each point is above or below the line is observable. These distances are called the y deviations from the line. The regression line (of y on x) has the property that the sum of squares of y deviations from the line is a minimum.

In a similar manner, visualize the distance each point is to the right or left of the line. These distances are called the x deviations. The regression line of x on y has the property that the sum of squares of x deviations from the line is a minimum. In general these two lines will not be the same.

Equations for the Two Regression Lines will be Presented. First, some notation will be introduced and defined. Returning to the scatter diagram, the following computations can be made:

(1) The average or mean of all X values, $\bar{X}$.

(2) The average or mean of all Y values, $\bar{Y}$.

(3) The standard deviation of X, Sx. Sx is a measure of how much the X values deviate from $\bar{X}$.

(4) The standard deviation of Y, Sy.

(5) The correlation coefficient, r.

(6) The average Y value for a fixed X value, Y'.

(7) The average X value for a fixed Y value, X'.

The equation for the regression line, Ly, of Y on X is:

$$Y' = r\frac{S_y}{S_x}\left(X - \bar{X}\right) + \bar{Y}$$

The equation for the regression line, Lx, of X on Y is:

$$X' = r\frac{S_x}{S_y}\left(Y - \bar{Y}\right) + \bar{X}$$

Some Observations Regarding the Value of r.

(1) If r has value of +1 or -1 then the two regression lines coincide. If r has value 0 then Ly will be a horizontal line while Lx will be vertical. Recall that Ly is a line fitted to the points of the scatter diagram to minimize Y deviations while Lx is fitted to minimize X deviations. When r=0 the points are so scattered that the two fitted lines are perpendicular. When $r=\pm1$ the points all lie on one line and the two fitted lines coincide.

(2) Test for Independence. If r is close to zero, there is not sufficient reason to doubt the independence of the two variables. If r is not close to zero, doubt is rejected with a certain degree of confidence. The question of confidence appears when one realizes that conclusions made about those subjects in the sample population may not be true about the entire population of all persons. That is, the sample may not accurately represent the entire population.

A statistical table is available to test for independence. For a specified number of subjects, N, in the sample population, the table provides two values, R and p. If the computed correlation coefficient, r, is greater than or equal to r (or less than or equal to -r) the variables X,Y are correlated. The chance of being wrong in this statement is the value of p.

TABLE USED

When $N = 80$ $r = .183$ with $p = .05$

$r = .217$ with $p = .025$

$r = .256$ with $p = .01$

In Appendix C (the 23 x 23 matrix) the correlation of the [r] (column 2) and speech range loss (column 1) is .57. By checking the sample table it is noted that not only is r higher than .183, it is higher than .217 and .256. Thus [r] is highly correlated with speech range loss.

(3) The value of the correlation coefficient, r, affects the slope of each regression line. If r is positive, then as one variable increases, so does the other. If r is negative then as one variable increases the other decreases.

Use of Methods of Analysis

Some General Observations made from the Matrix of Correlation Coefficient (Appendix C). Several general statements can be made regarding the results of the computations.

(1) The variables are, for the most part, highly correlated. The hearing loss variables (columns 1, 22, 23) representing speech range loss, low frequency loss and high frequency loss, are intercorrelated at the level of the reliability of a single test. This corroborates the procedure of reporting only the speech range loss to record amount of hearing loss. The primary factor common to the speech errors is hearing loss. Thus, the better the hearing, the better the speech.

(2) Variable 18, [θ], is significantly correlated to hearing loss, but in a negative manner. For instance, as hearing loss increases, the [θ] appears correctly more often in speech. It would appear that the [θ] has some property which is not common to all other speech sounds.

(3) Variable 6, [b], correlated relatively low with hearing loss, but correlating highly with variables which, in turn, correlate with hearing loss, i.e., [p l], and total errors. This suggests a methodological factor in addition to the hearing loss factor. One could speculate on why variable [b] has a low correlation with hearing loss. The visual cue, (manner of formation) beginning with the plosives, may have influenced the correlation of this variable.

Perhaps the amount of residual hearing is an important factor in the correct production of this sound.

Presentation of some Scatter Diagrams. Following (Figures 1-10) are some scatter diagrams which display the linear relationship that exists between pairs of variables.

Figure 1. This scatter diagram and regression line represent the relationship of speech errors to amount of hearing loss. Each point of the diagram represents one subject. For instance, one child with a hearing loss of 10 db., had a speech error score of 3. Several children clustering at the 20 db. and 25 db. levels had three to five articulation errors. Two children with 100 db. loss had as many as eighty articulation errors. By observing this line it may be stated that as hearing loss increases, speech errors increase.

Figure 2. A scatter diagram represents the thirty children attending public school. The vertical axis represents the age of the subject and the horizontal represents the number of articulation errors. On this diagram the dark purple dots represent subjects with moderate hearing loss; pencil markings represent subjects with slight hearing loss. For instance, there are five twelve-year-old children; three with slight losses; two with moderate losses. Of these five children, one had two articulation errors; one had four errors; one had nine errors; one had twelve errors; and one had fourteen errors. The regression line had not been presented by the use of the formula, but has been estimated by the writer to

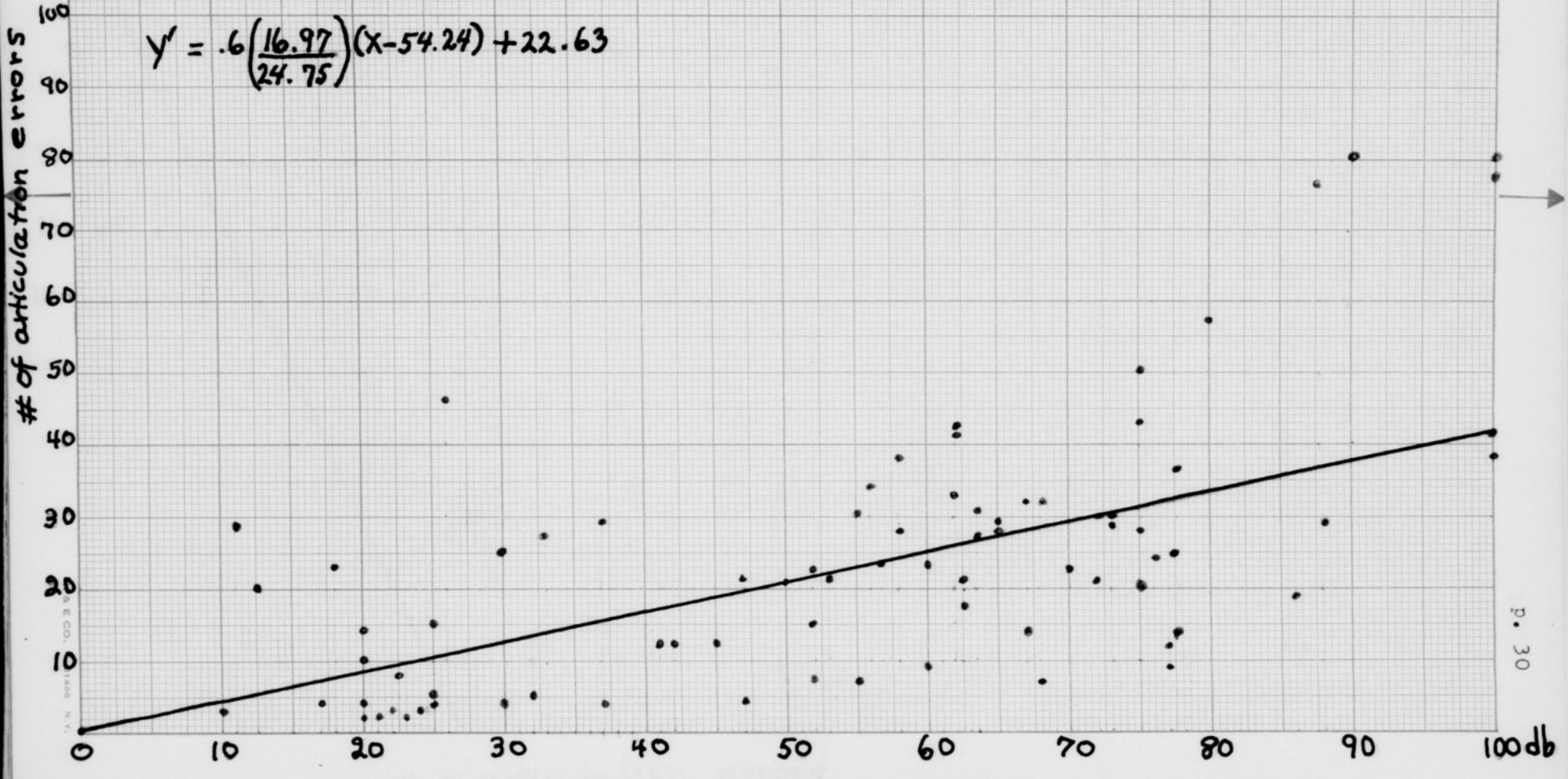
Error in one position = 1 point
Error in two positions = 2 points
Error in three positions = 4 points

Figure 1

ERRORS VS. Hearing Loss

X	Y	$\bar{X}$	S_X	$\bar{Y}$	S_Y	r
1	21	54.24	24.75	22.63	16.97	.6

$$Y' = .6\left(\frac{16.97}{24.75}\right)(X-54.24)+22.63$$



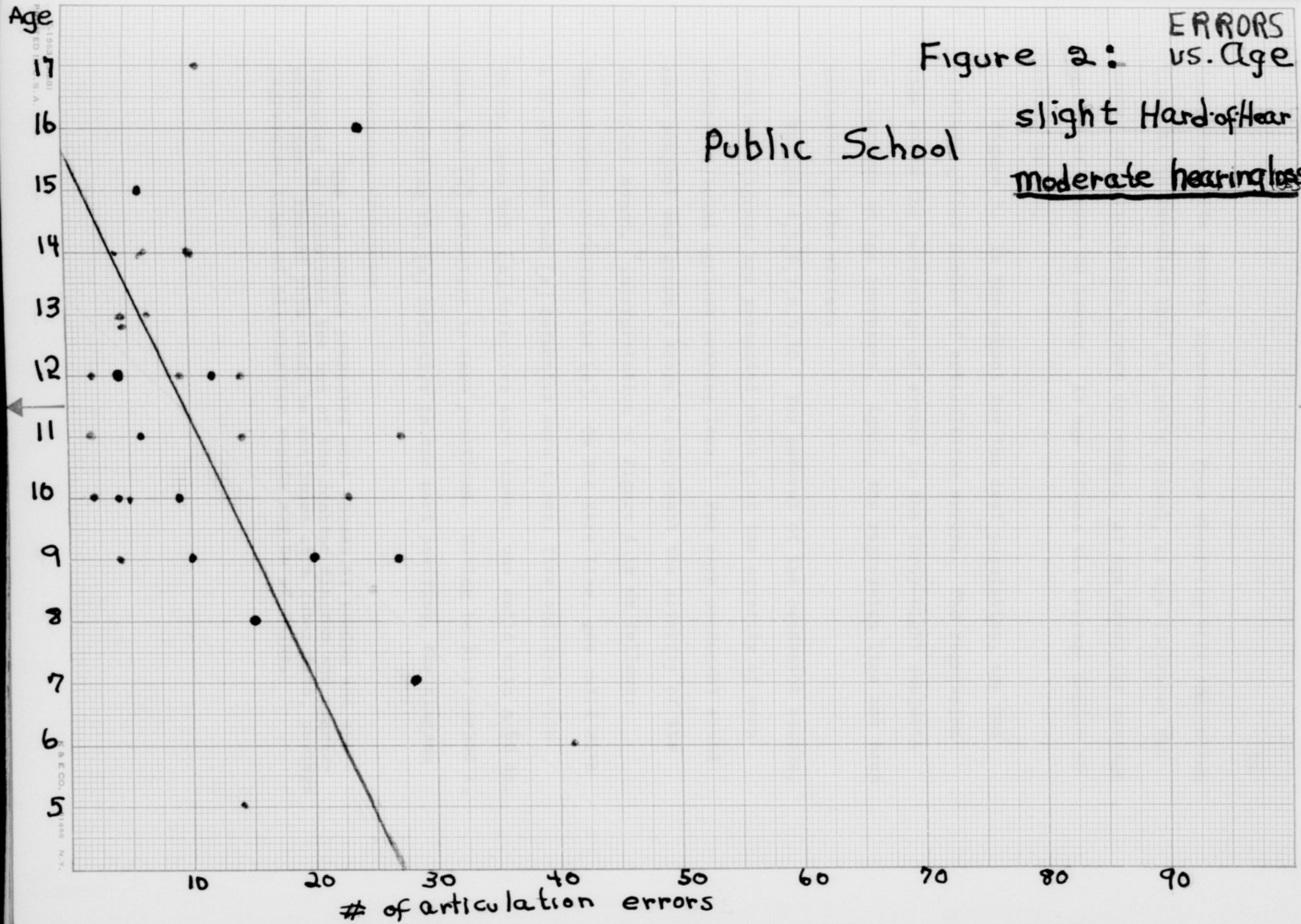


Figure 2: ERRORS vs. Age

demonstrate its general direction. From observing this regression line, it is revealed that in public school, as age increases the number of articulation errors decreases. At age seven the average number of errors is twenty. At age fifteen the average number of errors is two.

Figure 3. In the school for the deaf population, age was plotted against number of articulation errors. The regression line shows the percentage of errors in the forty-eight subjects to increase as age increases. Again, the regression line has been estimated by the writer.

Figures 4,5,6,7,8,9,10. For several of the consonant sounds, scatter diagrams are presented which plot the severity of each defective sound against hearing loss.[1] For each consonant sound each subject was given a score to represent the severity of the defective sound. Interpretation of Figure 4 is as follows:
The diagram represents the [s]. On the zero line, one child with a 10 db. loss had [s] defective zero times; five children with 20 db. loss had [s] defective zero times; one child with a 60 db. loss had [s] defective in zero positions. Moving to line marked 1, representing the [s] defective in one word position, the diagram

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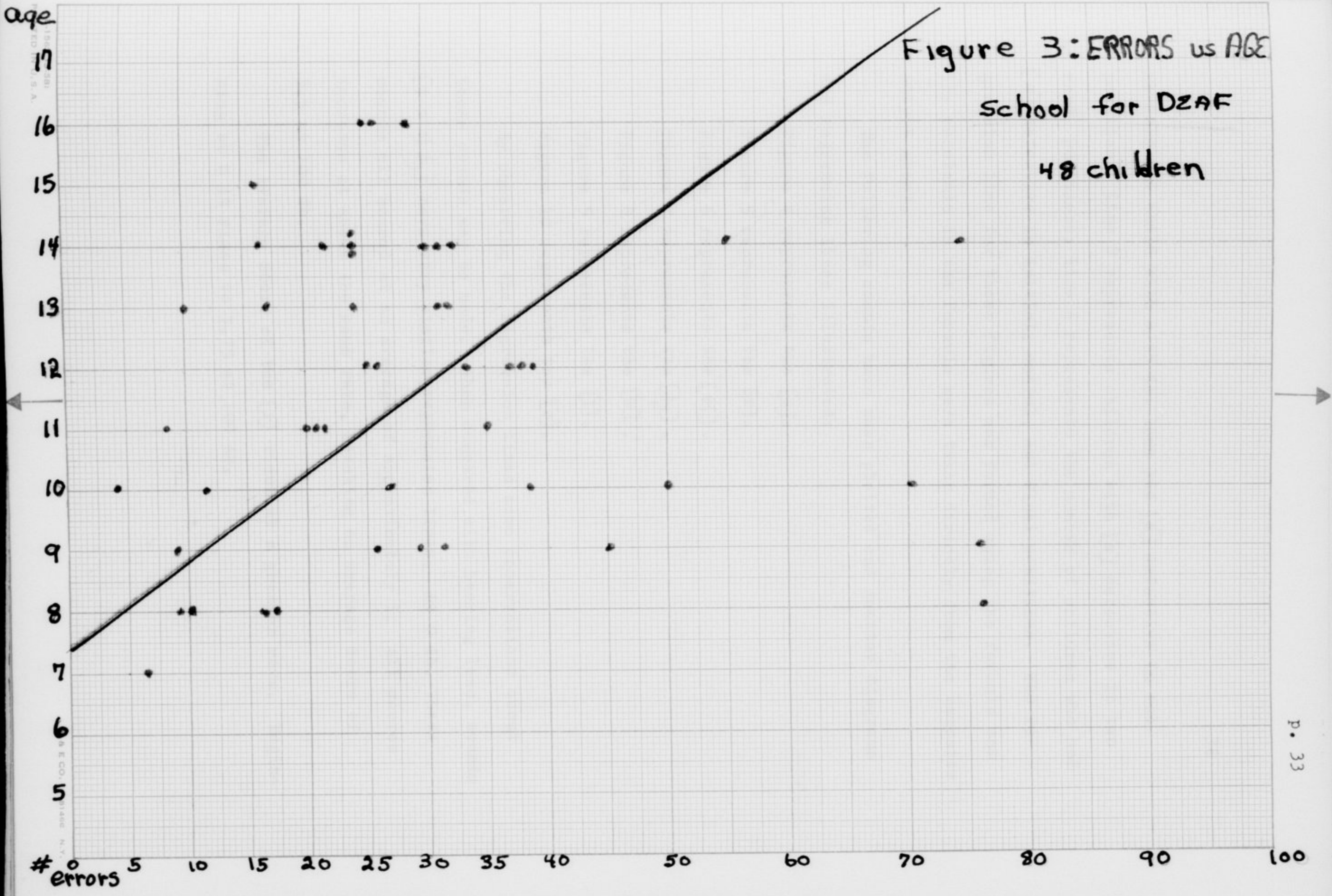
[1] The six sounds presented were chosen at random and are included to illustrate the use of the scatter diagram and regression line. Should this study be continued at a later date, perhaps regression lines of all nineteen sounds may be of value.


age
17
16
15
14
13
12
11
10
9
8
7
6
5
errors
0
5
10
15
20
25
30
35
40
50
60
70
80
90
100
Figure 3: ERRORS vs AGE
School for DEAF
48 children

reveals one child with a 45 db. loss had [s] defective in one position. Line 2 represents children with [s] defective in two word positions; line 4 represents the number of children who had [s] defective in initial, medial, and final positions. The regression line for these figures was formed using the formula and the constants in the formula were taken directly from the computer output sheet.

The following sounds have been plotted and scatter diagrams and regression lines illustrated:

Figure 4 represents the [s].

Figure 5 represents the [z].

Figure 6 represents the [tʃ].

Figure 7 represents the [dʒ].

Figure 8 represents the [θ].

Figure 9 represents the [l].

Figure 10 represents the [r].

By observing the regression lines some observations about these sounds may be made. When compared with hearing loss, sounds [s z tʃ dʒ] have very similar regression lines. At 0 db. these sounds all scored at an average of approximately 1. All scores increase at about the same rate, reaching an average score of 3.5 at 100 db.

The average score of the [r] rises at a greater rate. Beginning at 0 it rises to 3.75 at 100 db.

The [θ] was the only sound studied which has a score that decreases as hearing loss increases. Beginning with an average of 2.75, the score drops to .75 at 100 db.

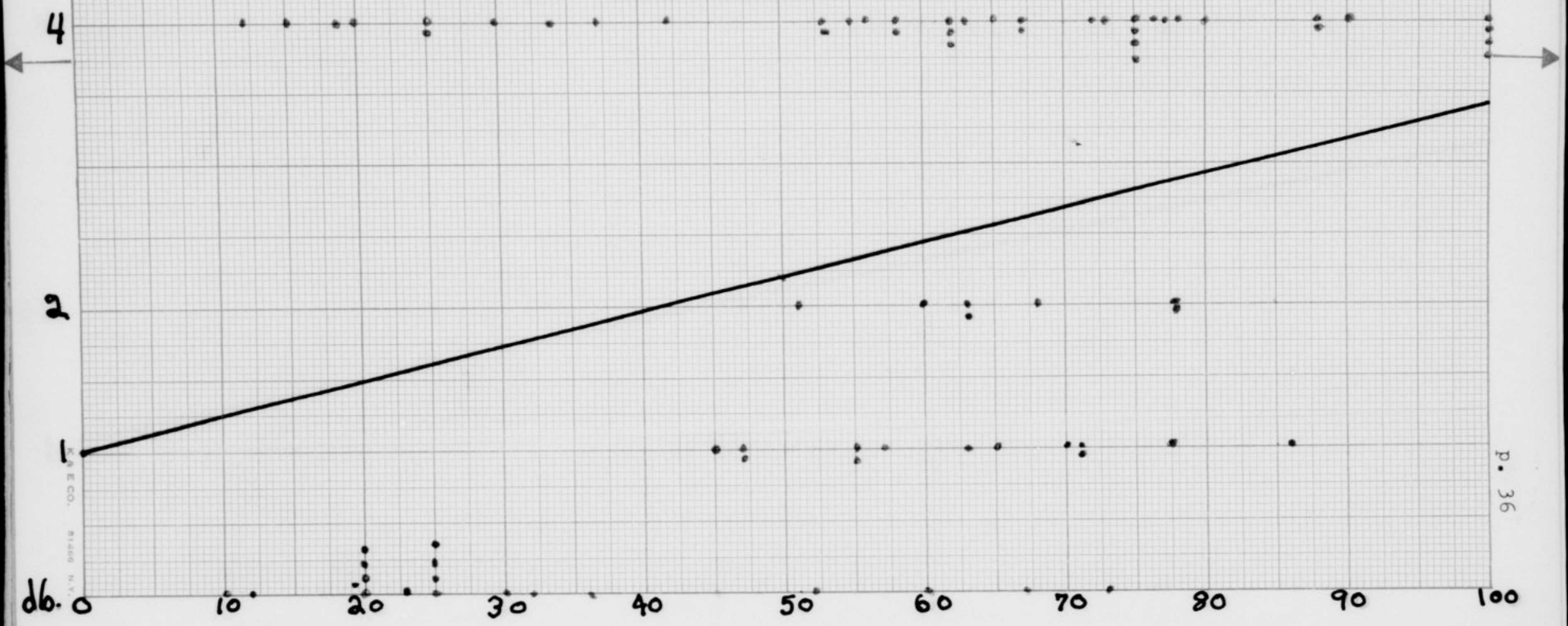
In general one may compare the correlation coefficients with the clustering of the points to the regression lines. These coefficients range from a low of .28 for [z] to a high of .57 for [r].

S Regression Line

Figure 4

X	Y	$\bar{X}$	S_x	$\bar{Y}$	S_y	r
1	15	54.24	24.75	2.3	1.73	.32

$$Y' = .32\left(\frac{1.73}{24.75}\right)(X-54.24)+2.30$$

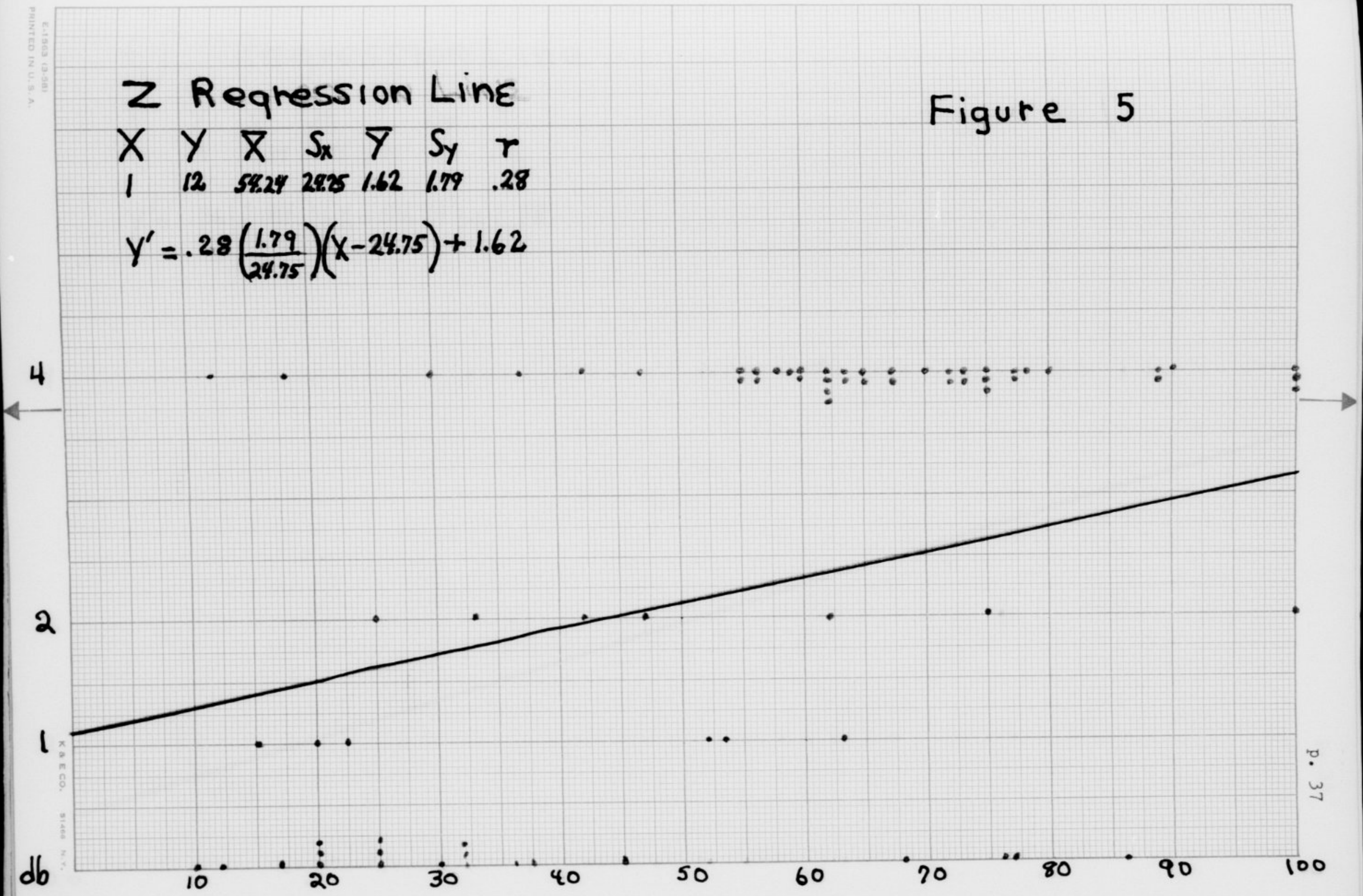


Z Regression Line

X	Y	$\bar{X}$	S_x	$\bar{Y}$	S_y	r
1	12	54.24	24.25	1.62	1.79	.28

$$Y' = .28\left(\frac{1.79}{24.75}\right)\left(X - 24.75\right) + 1.62$$

Figure 5

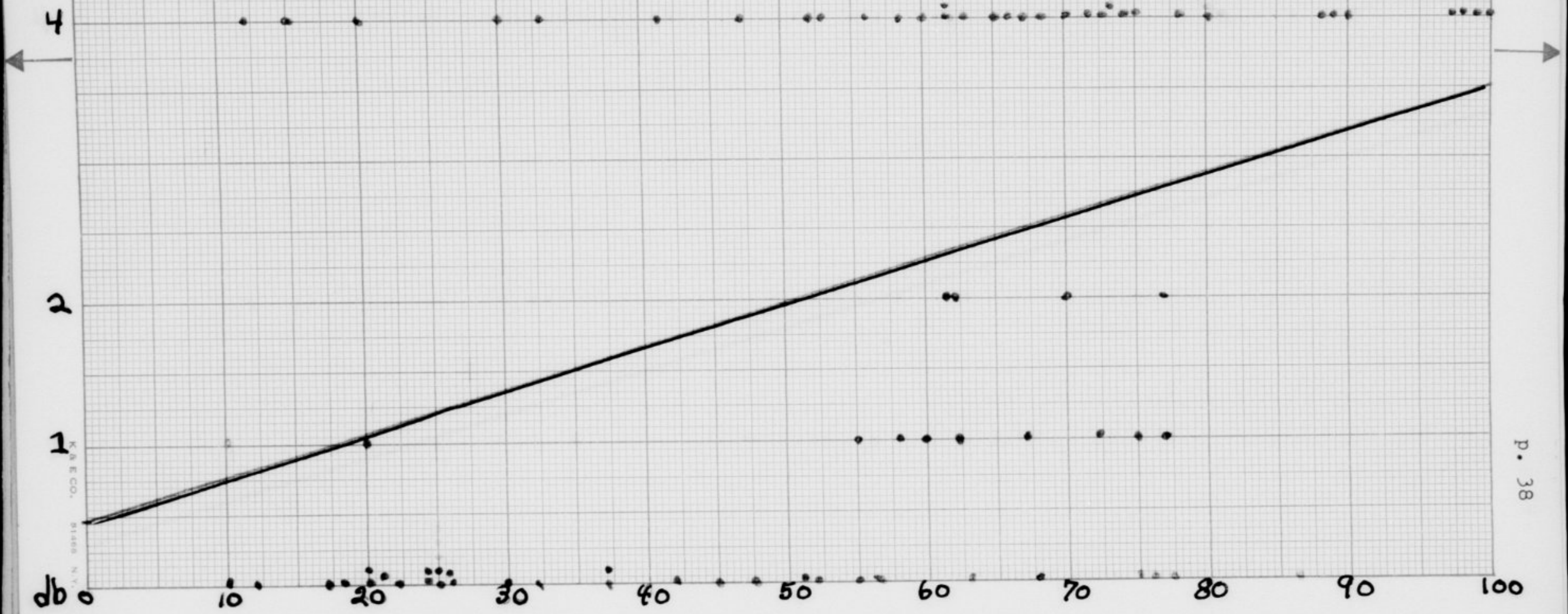


tʃ Regression Line

Figure 6

X	Y	$\overline{X}$	S_x	$\overline{Y}$	S_y	r
1	20	54.24	24.75	1.88	1.84	.36

$$Y' = .36\left(\frac{1.84}{24.75}\right)\left(X - 54.24\right) + 1.88$$

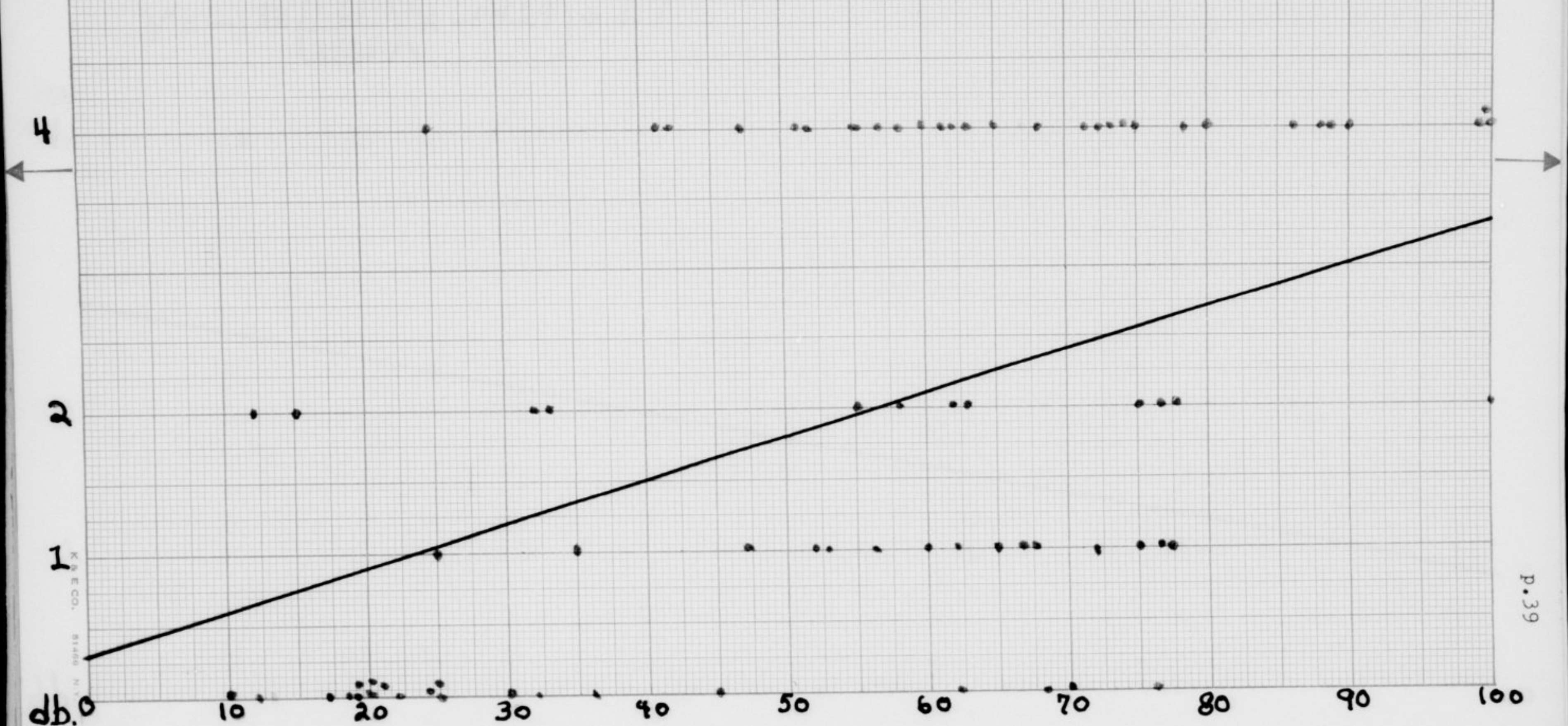


d_3 Regression Line

X	Y	$\bar{X}$	S_x	$\bar{Y}$	S_y	r
1	19	54.24	24.75	1.93	1.63	.53

$$Y' = .53\left(\frac{1.63}{24.75}\right)(X-54.24)+1.93$$

Figure 7

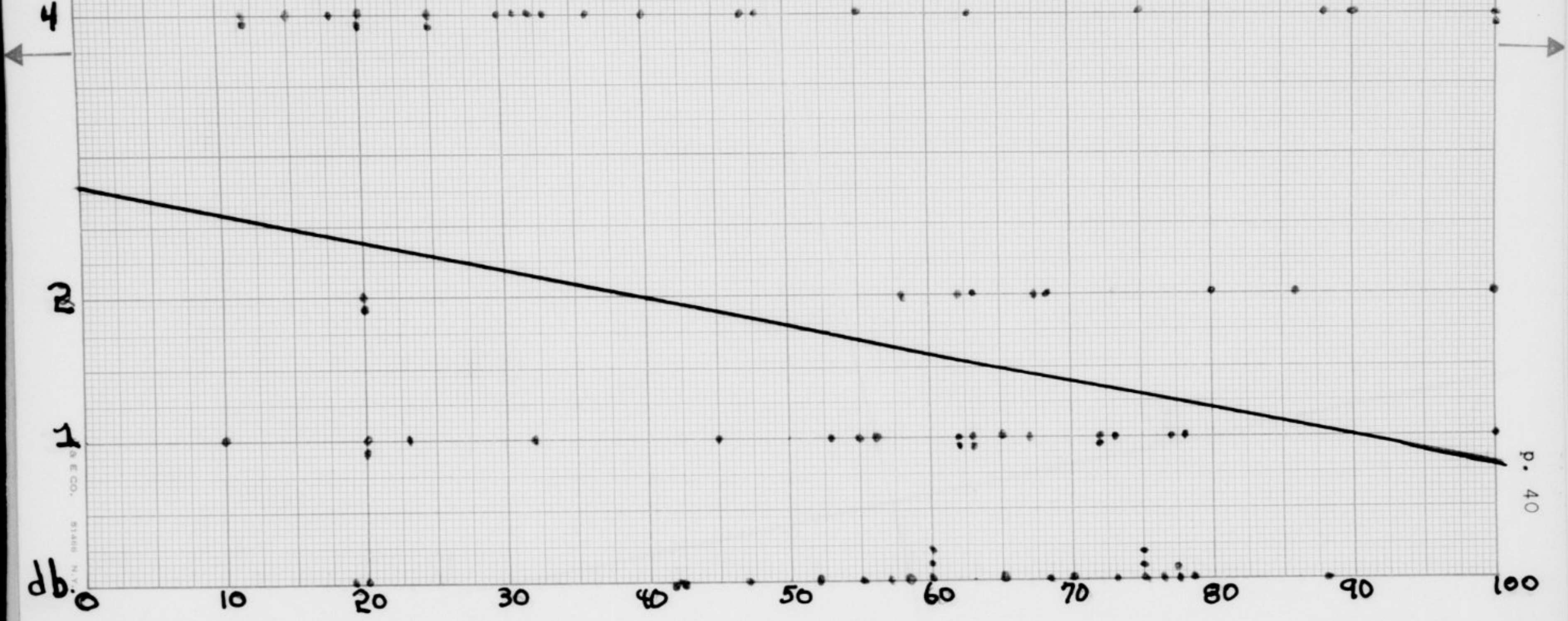


θ Regression Line

Figure 8

X	Y	$\bar{X}$	S_x	$\bar{Y}$	S_y	r
1	18	54.24	24.75	1.7	1.61	-.32

$$Y' = -.32\left(\frac{1.61}{24.75}\right)\left(X - 54.24\right) + 1.7$$

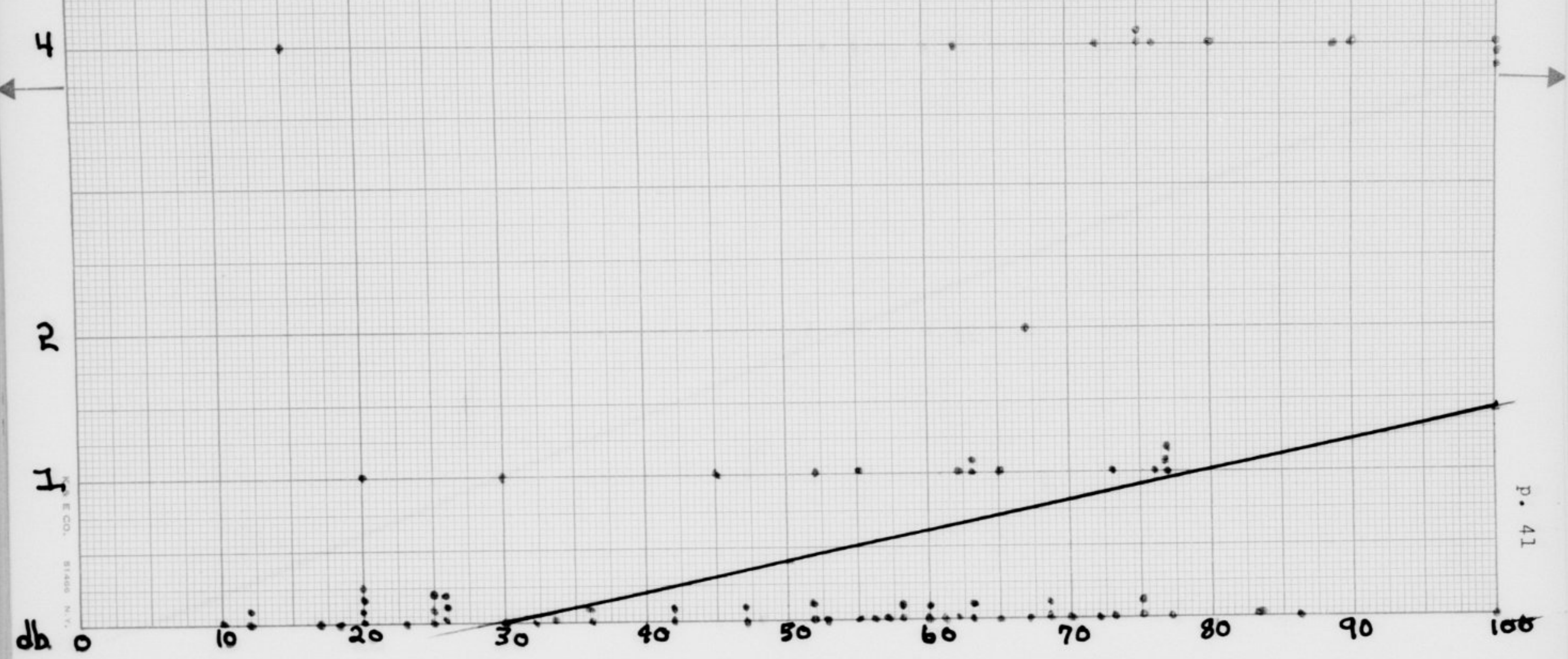


l Regression Line

Figure 9

X	Y	$\bar{X}$	S_X	$\bar{Y}$	S_Y	r
1	3	54.24	24.75	.47	1.09	.43

$$Y' = .43\left(\frac{1.09}{24.75}\right)\left(X - 54.24\right) + .47$$

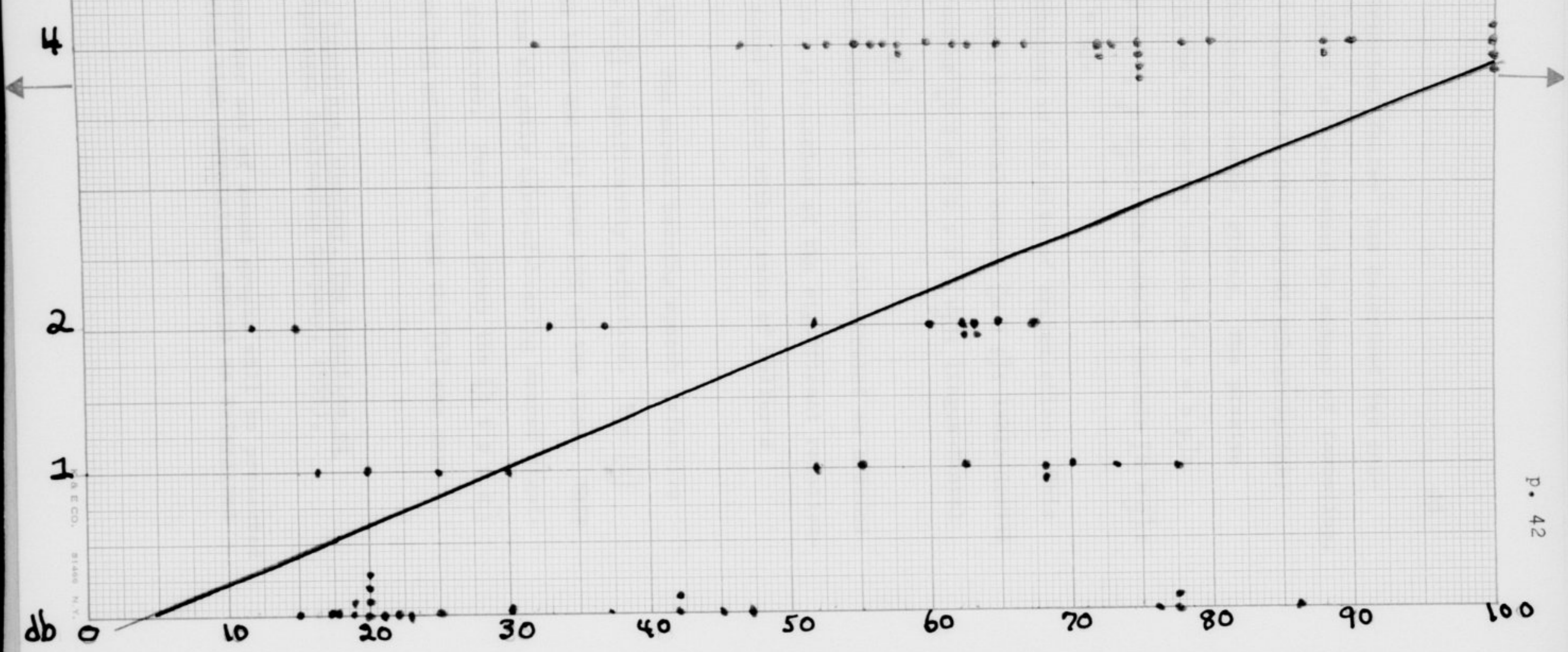


r Regression Line

X	Y	$\bar{X}$	S_x	$\bar{Y}$	S_y	r
1	2	54.24	24.75	2.0	1.7	.57

$$Y' = .57\left(\frac{1.7}{24.75}\right)(X - 54.24) + 2.0$$

Figure 10



Analyzing Sound Categories. Heller[1] has described two consonant categories. The first is categorized by manner of formation. This category is further classified into several sub-groupings; plosives, fricatives, sibilants, nasals, glides. The plosive sounds are [p b t d k g]; the fricatives include [f v θ h ð]; the sibilants include [s z ʃ tʃ ʒ dʒ] ; the nasals include [m n ŋ] ; and the glides are [l r w y].

The second major category is the site of articulation. This may also be sub-grouped into bi-labial sounds [m b p]; labio-dental sounds [f v]; lingua-alveolar [t d n l s z r tʃ dʒ]; lingua-dental [θ ð] ; and lingua-velar [k g].

Each of these classifications has been illustrated on a sound graph. Following will be a discussion of the significant relationships that exist among sound graphs within each of Heller's groupings.[2]

Plosives: Figure 11. The normal hearing speech defective group did not have [p b t d] significantly defective. The [k] was defective 35% of the time and [g] over 15% of the time. This is of interest because the slightly hard-of-hearing scored significantly better on all plosives. For this group the [b t p d g] were defective less than 15% of the time and the [k] was most

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[1] Morris Heller, Functional Otology, The Practice of Audiology (New York: Springer Publishing Company, 1955), pp. 178-183.

[2] In addition, another set of sound graphs will be presented which were formed by using high correlation groups as determined by the 1620 computer.

often defective at 16%. Because [k g] are not visual sounds, one might expect the hard-of-hearing groups to have at least as much difficulty as the normals, but that was not the case. In the moderate hearing loss group, [d], is noticed as most defective at 33%. All other sounds remain below the 20% level.

As was expected the educationally and profoundly deaf show a sharp increase in errors. All sounds cross the 50% mark except [b] found in the educationally deaf group. Apparently residual hearing is especially important in the production of this sound.

Nasal sounds: Figure 12. Nasal sounds show a similar pattern. Normal hearing children have almost zero difficulty with these sounds. The moderate and slight public school groups score low at about 10%. On [m] the educationally deaf group continues to score at approximately 13%.

Of the two nasal sounds, [m] appears to be the easier to form. Perhaps this is due to the visual cue. It must be mentioned that some residual hearing appears to be extremely important in producing the [m] sound, since the profoundly deaf, who have the same lip reading advantages, scored significantly lower.

Glides: Figure 13. The [l] is more difficult (45% defective) for the normal hearing group, yet it is easier to articulate in the slights (11%), moderates (16%) and the educationally deaf (21%). Perhaps again the visual cues are causing the hard-of-hearing groups to score higher. The profoundly deaf, however, misarticulate this sound 50% of the time. A significant rise is noted from the 21%

of the educationally deaf. Residual hearing must be most helpful in making this sound.

The [r] sound does not seem to depend on residual hearing for correct production, as both deaf groups misused that sound over 90% of the time. This [r] seems to be directly proportional to the amount of hearing. Of the two sounds, the hard-of-hearing groups find [r] more difficult that the [l] sound. The normal hearing speech defective group finds [r] easier of these two sounds.

Fricatives: Figure 14. Of this group of sounds, the [θ] appears to be the most difficult. Almost 90% of the normal hearing and slight hard-of-hearing misarticulated this sound. Then, of greater interest, only 67% of the moderate hearing loss group mispronounced the [θ] , and the educationally deaf misuse it only 55% of the time. Thus, the line moves inversely from what one might expect. It was felt until this study was complete that auditory discrimination was most important in learning this sound. Yet, as hearing loss increased, the percentage of errors decreased.

The [f] sound showed a directly proportioned upward line as hearing loss increased - from 5% in the slights to 57% in the profoundly deaf.

The [v] is 37% defective in the normal group and drops back to the 25% level for all the hard-of-hearing group. The visability of this sound must be an aid, either formally taught or independently learned. And the presence or absence of hearing acuity has little bearing on correct sound production.

The [v] presents an irregular pattern, difficult to interpret. It is 42% defective in the normals; 21% in the slights; 43% in the moderates; only 20% in the educationally deaf and a relatively low 25% in the profoundly deaf. It appears that no general fricative pattern is established. That is, the manner of formation is not significant in determining sound difficulty.

Sibilants: Figure 15. The sibilants, on the other hand, present a distinct pattern. The normals have most difficulty with [s] and [z], both over 50% defective. In every case the sibilants drop back to less % difficulty in the case of the slight group. Five of the six sibilants (excluding [tʃ]) take an upward turn ranging from 42% - 75%; and all sibilants take another rise from the educationally deaf (65% - 85% difficulty); all take another rise in the profoundly deaf group (from 75% - 100%). It appears that manner of formation for the sibilant sounds is a significant factor in correct sound production.

Plosives

Figure 11

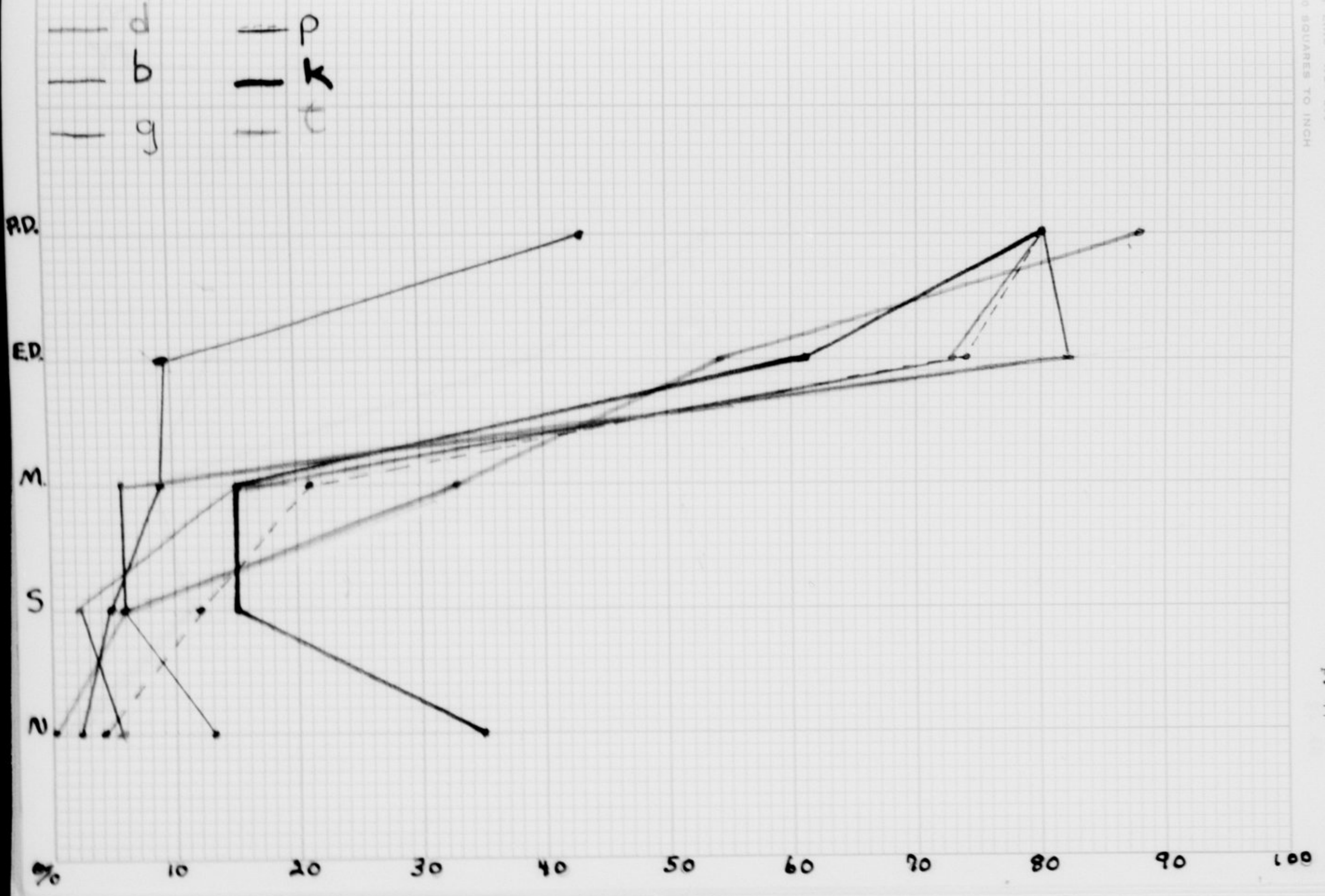
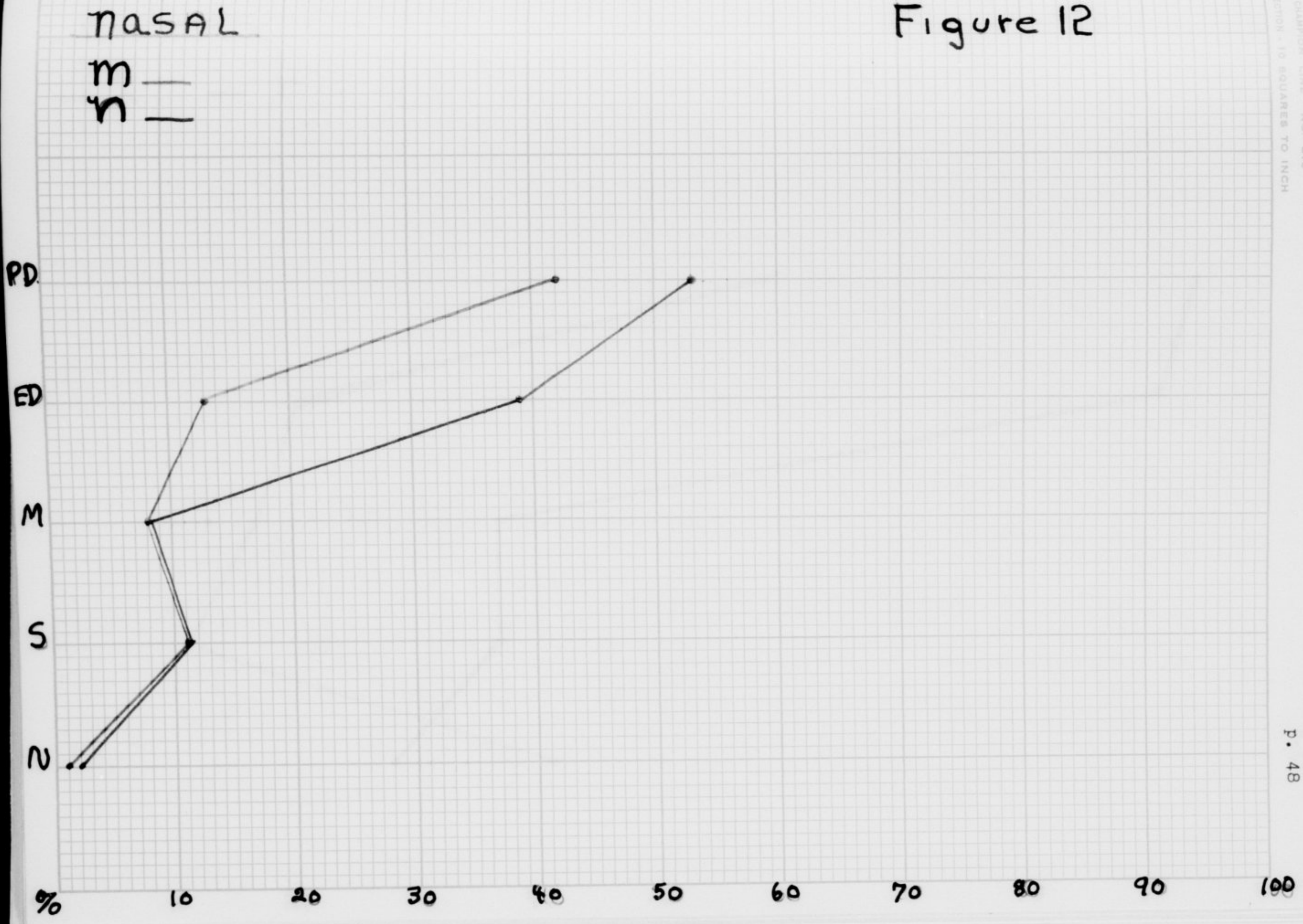
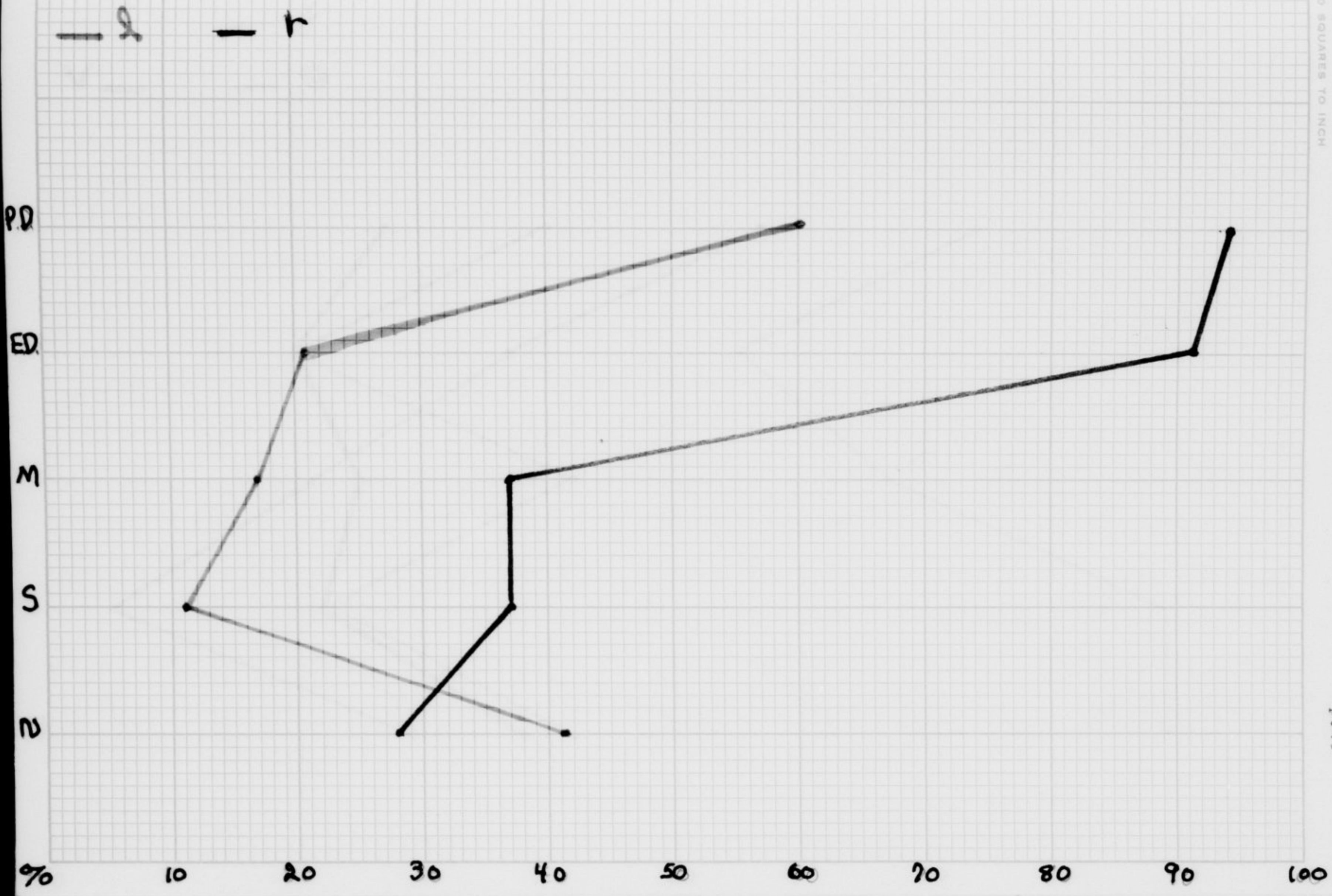


Figure 12



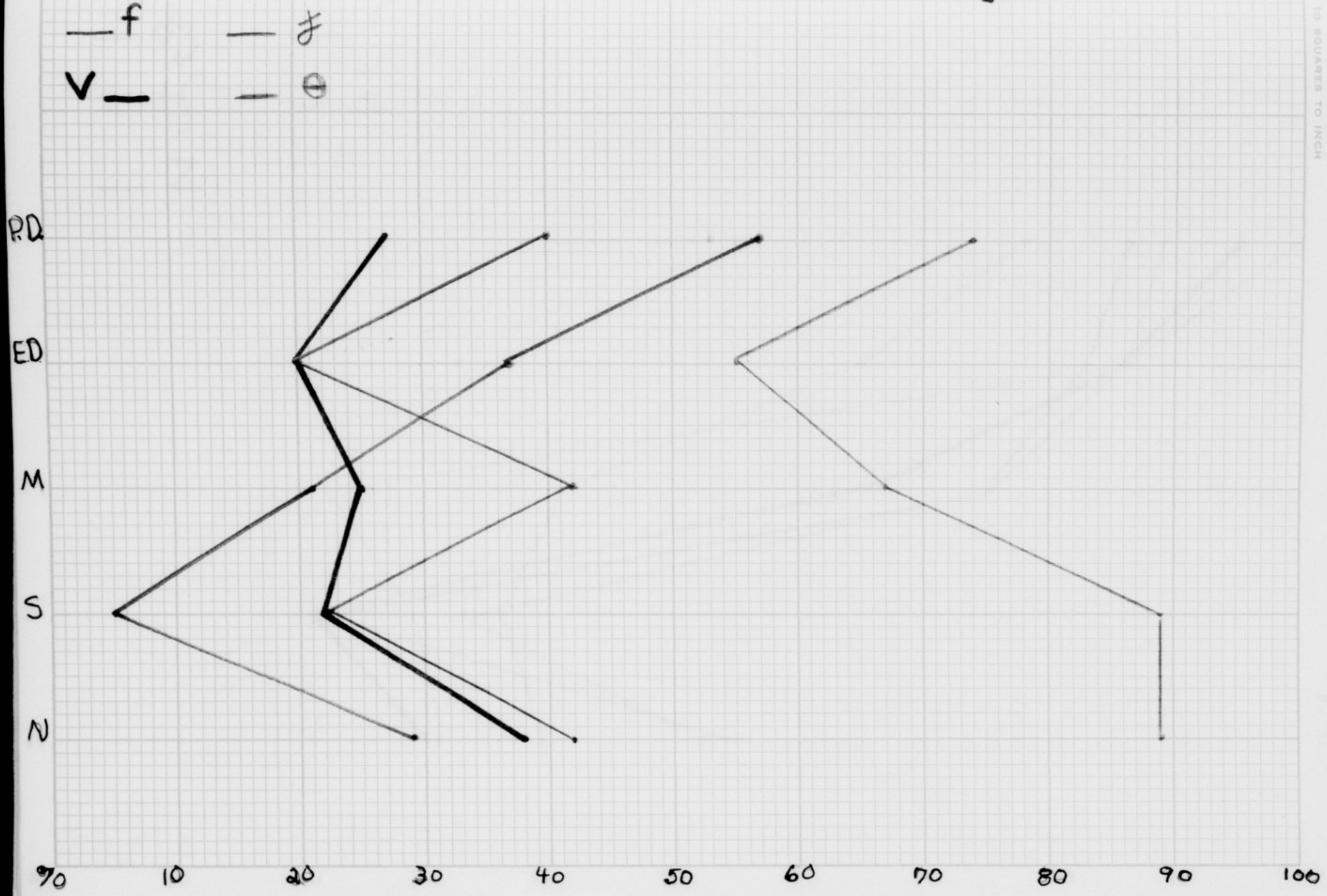
Glides

Figure 13



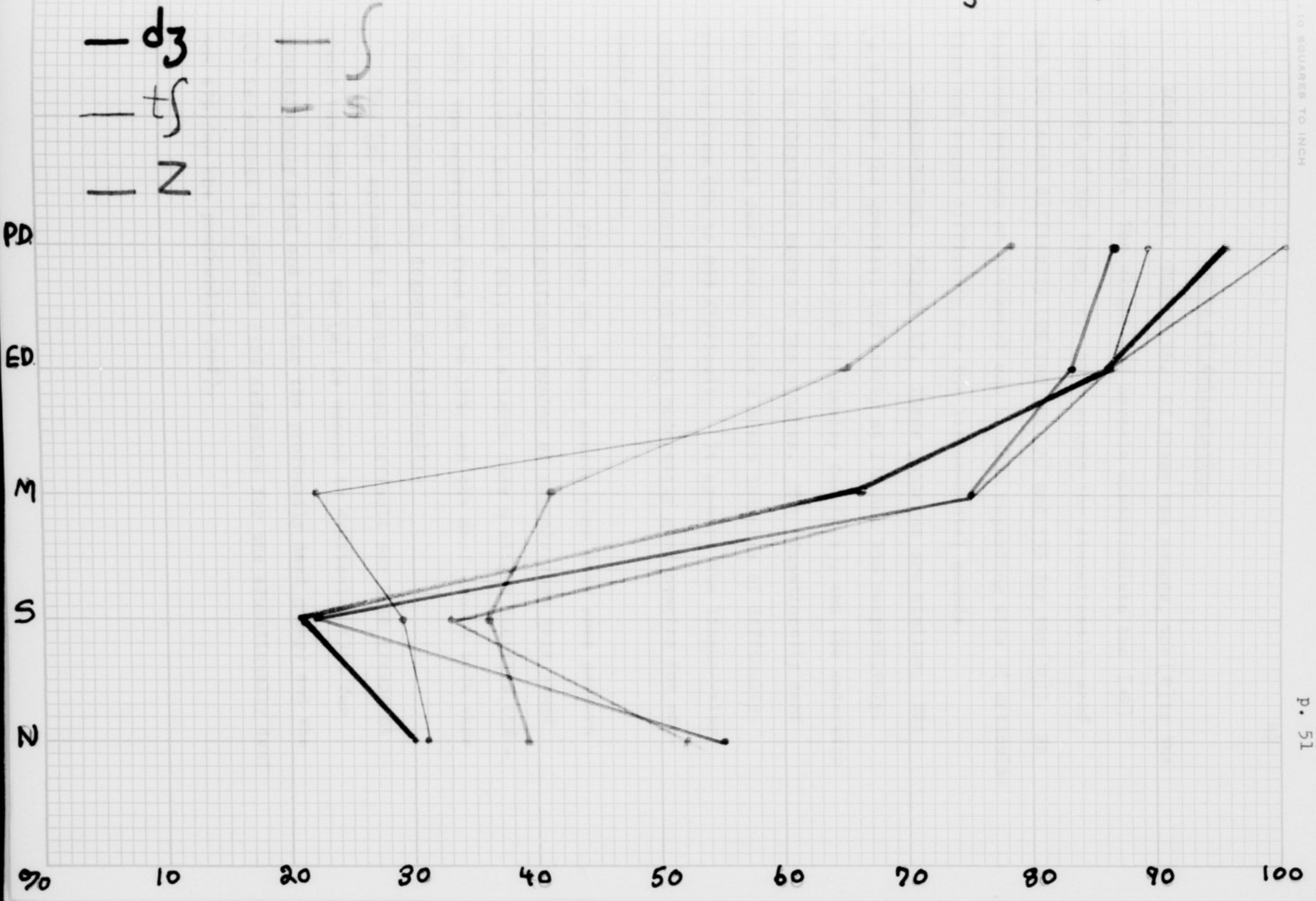
Fricatives

Figure 14



Sibilants

Figure 15



Site of Articulation

Lingua-Dental: Figure 16. Of these two sounds, the [θ]is the more difficult. The slight and normals misarticulate the [θ] almost 90% of the time. For both sounds the educationally deaf had the least difficulty (9% for the [ð] and 55% for the [θ]). No distinct pattern or statement can be made regarding site of articulation and sound difficulty for the lingua-dental sounds.

Lingua-Velar: Figure 17. These patterns are similar. The [g k] show the greatest difficulty at 17% and 35% respectively. The slights show 3% and 16% difficulty for [g k]; and the moderates have an identical score to the slights. The educationally deaf and profoundly deaf groups show a sharp increase of difficulty ranging from 65% to 85% difficulty. It appears the lingua-velar sounds are dependent on at least moderately good hearing for adequate production.

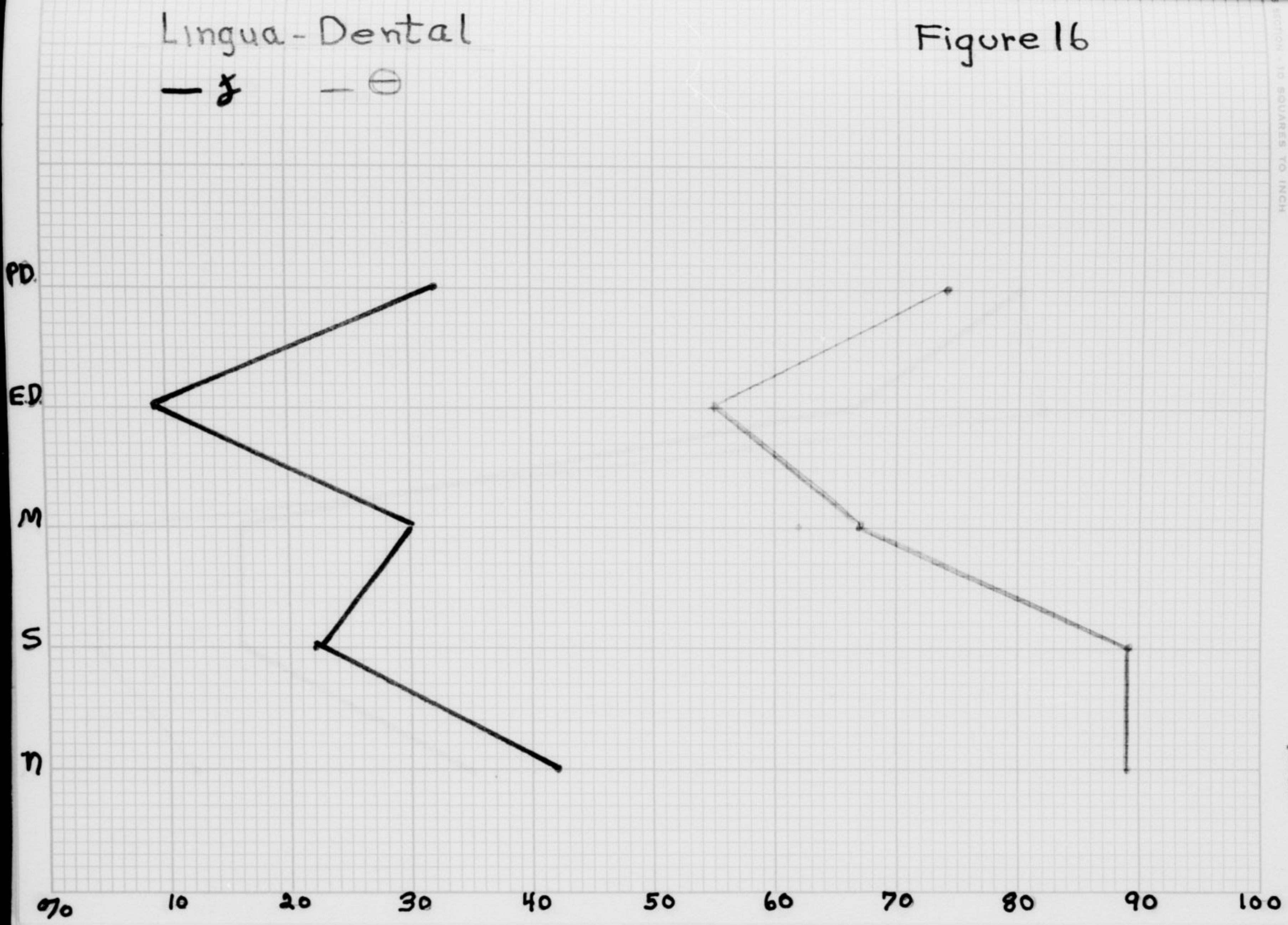
Bi-Labial: Figure 18. These sounds also show some pattern similarity. An insignificant number of normals show this sound defective (less that 2%); the slights show a slight increase (5% - 10%); the moderates from 8% to 12%; and the deaf groups both show a sharp increase in degree of difficulty.

The [p] appears to be the most difficult for both groups at about the 80% level. The [m] is second in difficulty (39% for educationally deaf and 54% for the profoundly deaf group) and the [b] is easiest to produce (12% defective for the educationally deaf and 47% for the profoundly deaf).

Labio-Dental: Figure 19. For the normal group, these sounds are approximately 30% - 40% defective. The slight and moderate groups reveal a drop in difficulty. The [v] sound drops even lower in the educationally deaf (9%); yet the [f] veers sharply upward to the 35% level. These sounds continue their upward climb in the profoundly deaf group with [v] at 32% and [f] at 57%. Of these two sounds we see the degree of difficulty changing. For the moderate, slight and normal group, the [v] is most difficult. For the deaf groups, however, [f] becomes more difficult.

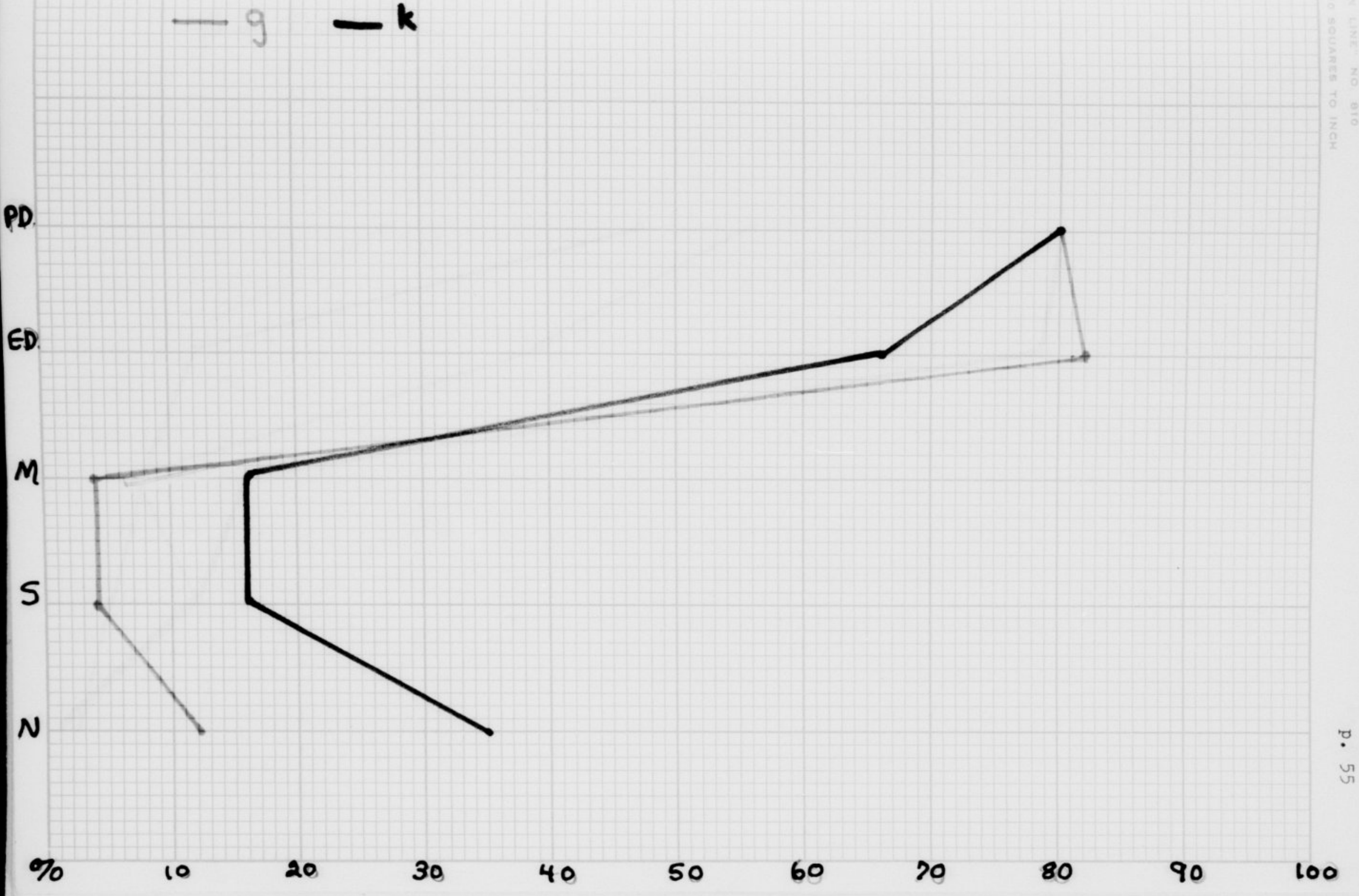
Lingua-Alveolar: Figure 20. These ten sounds show no consistency except that the profoundly deaf have most difficulty, as might be expected. A few observations may be made. The [s] appears to be the most difficult for all hard-of-hearing groups. The [t l z dʒ] show the same pattern in that the slight group has less difficulty than the normal group and the line rises steadily in difficulty through all groups.

Figure 16



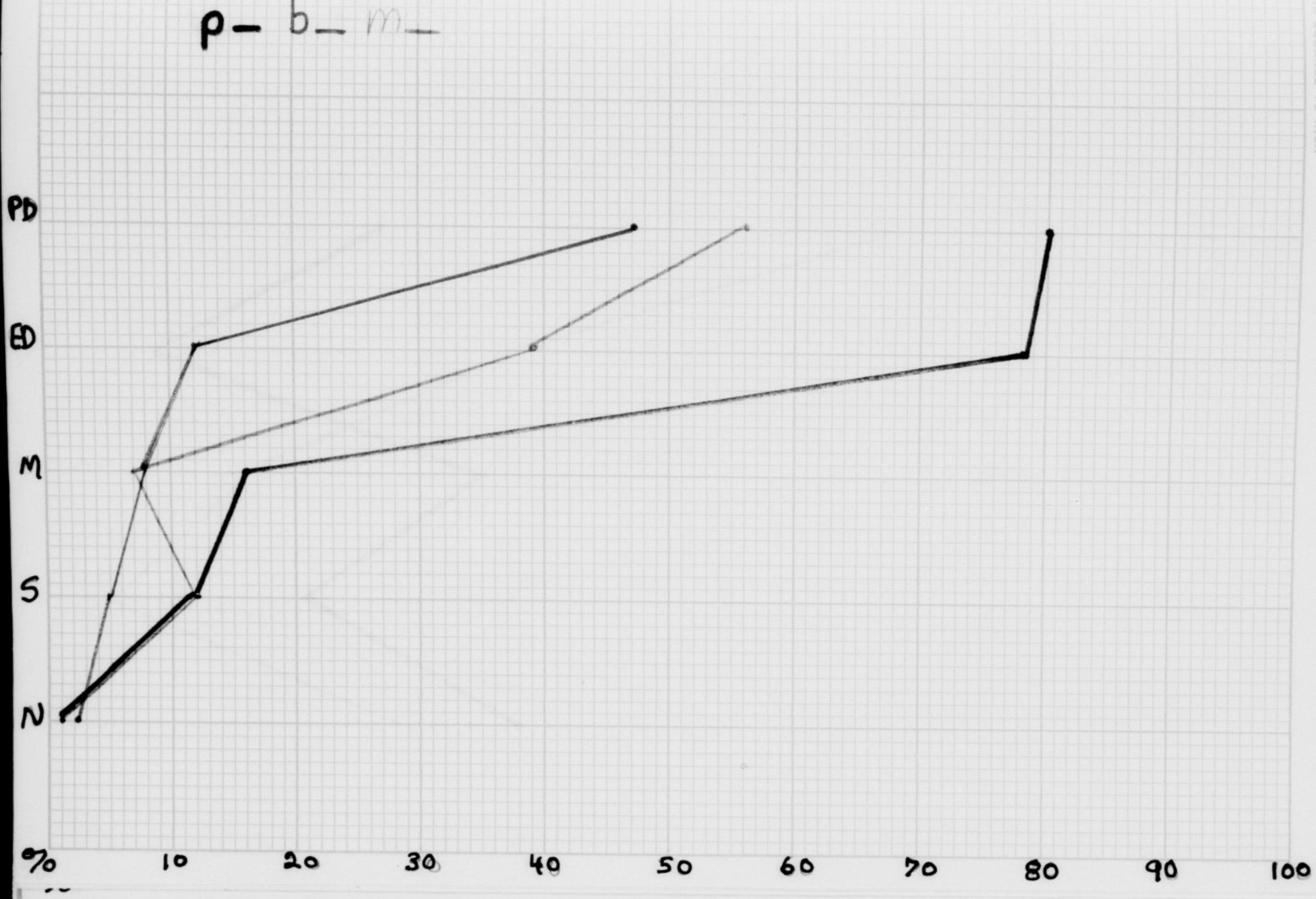
Lingua-Velar

Figure 17



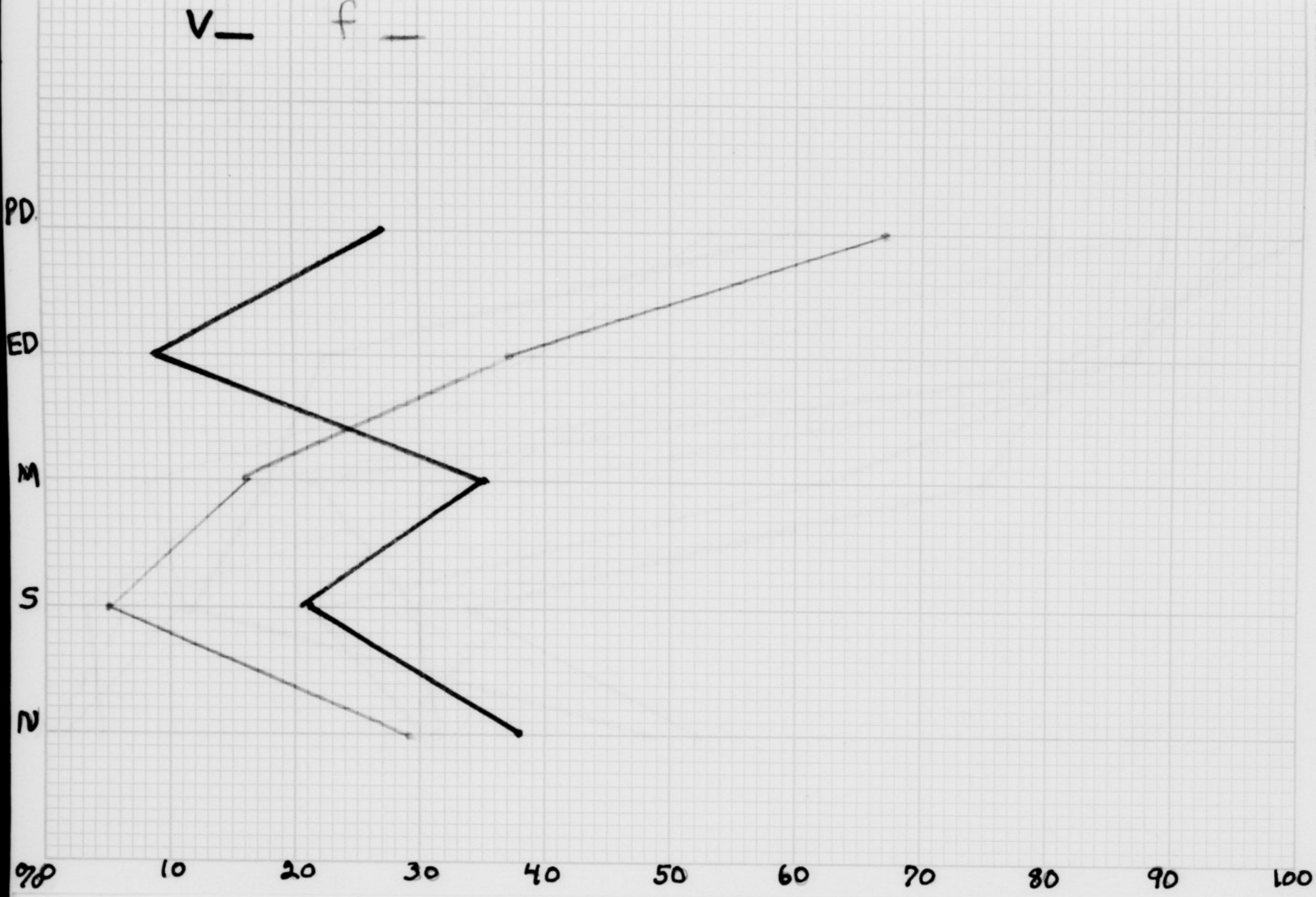
Bi-Labial

Figure 18



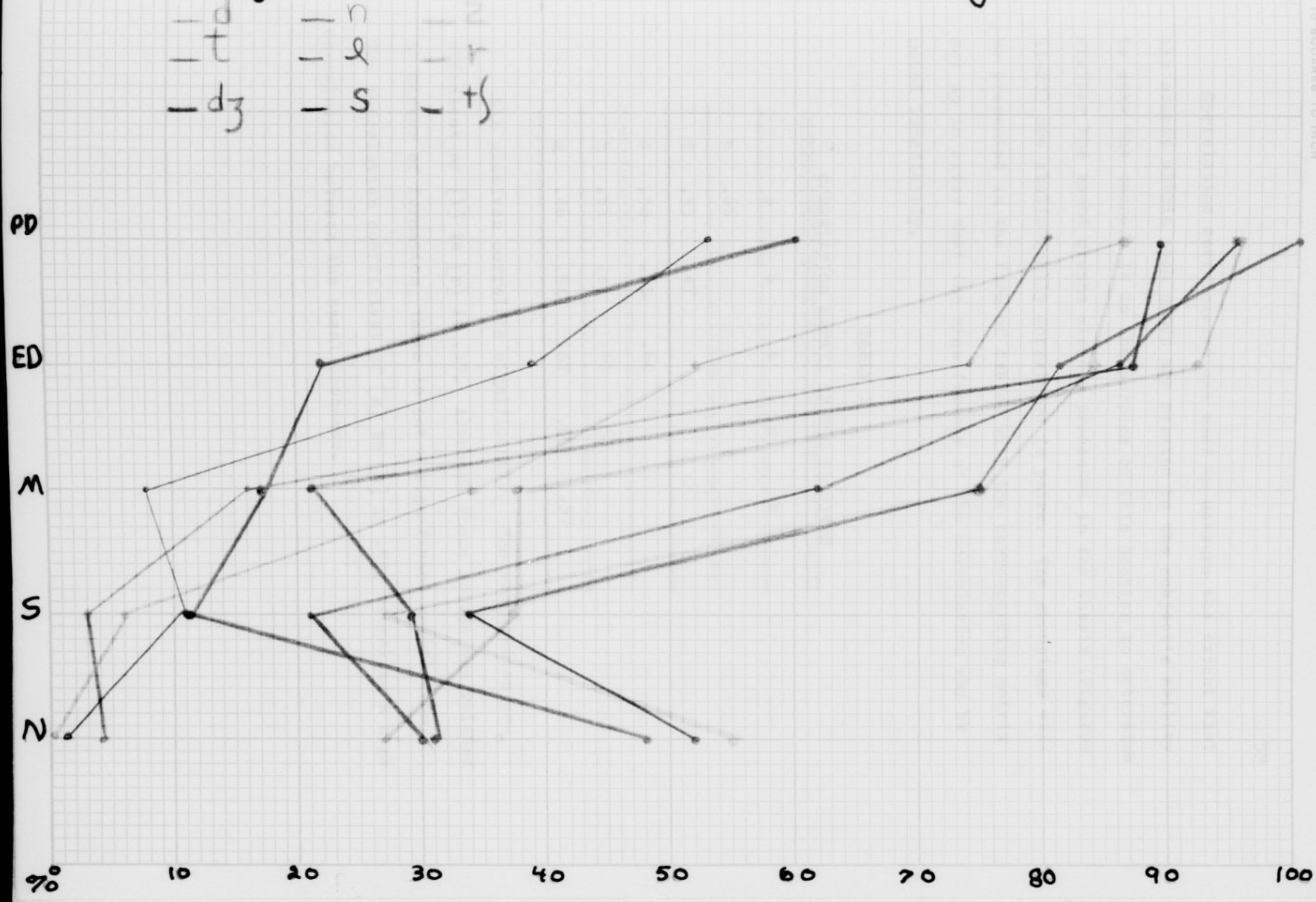
Labio-Dental

Figure 19



Lingua-Alveolar

Figure 20



Correlation coefficients are used to measure the extent that the sounds within each group are related to the subject's ability to make the sound. It is the purpose of this section to determine whether the sound graphs already presented in the thesis (Figures 11-20) are statistically correlated in pairs. The groupings will be presented in the form of tables with the corresponding matrix set up in order that the significance of the correlation may be noted immediately.

TABLE 1

CORRELATION MATRIX OF THE PLOSIVES

	p	b	t	d	k
b	.66				
t	.55	.47			
d	.58	.38	.60		
k	.61	.41	.61	.57	
g	.46	.34	.47	.65	.57

All plosives correlate significantly. The correlation coefficient of [l] to [r] is .17. Although these sounds are related in manner of formation, there is not a significant correlation. The correlation coefficient of [m] to [n] is .55, revealing a high correlation between the nasal phonemes.

TABLE 2

SOUND CORRELATION MATRIX

FRICATIVES				SIBILANTS				
	f	v			s	z		
v	.54			z	.21			
θ	.15	.21		ʃ	.37	.33		
ð	.50	.35	.39	tʃ	.23	.48	.48	
				dʒ	.21	.43	.36	.37

The fricatives contain [θ] and [ð] which have very unusual correlation patterns. The [θ] has a negative correlation with hearing and very low correlation with other sounds. The .39 with [ð] is the highest for [θ] and one of the few significant correlations. The [ð] is the only sound with significant correlation to hearing. Highest correlations for [ð] are with [l b p]. In the sibilant grouping the [s] has a low correlation with all other sounds in this group. The other sibilants have significant correlations.

The correlation coefficient of the [g] to [k] is .57, revealing a high correlation between the lingua-velar sounds. The correlation between the [ð] and [θ] is .39, revealing a significant correlation between the lingua-dental phonemes. The correlation coefficient between [f] and [v] is .54, revealing a high correlation between the labio-dental sounds. The bi-labial sounds reveal a .43 correlation between [m] and [p]; and a .66 correlation between [b] and [p]. The labio-dental sounds are highly correlated.

TABLE 3

CORRELATION MATRIX OF THE LINGUA-ALVEOLAR PHONEMES

	t	d	n	l	s	z	v	θ	dʒ
d	.60								
n	.50	.42							
l	.49	.41	.67						
s	.42	.32	.30						
z	.28	.38	.08	.24	.21				
r	.39	.47	.18	.17	.33	.41			
θ	.04	.05	.05	.20	.00	.14	-.04		
dʒ	.40	.48	.19	.21	.21	.43	.36	-.04	
tʃ	.31	.31	.16	.16	.23	.40	.47	.04	.47

Perhaps the most striking relationships involve the sounds [n] and [l]. Each of these sounds fails to correlate significantly with sounds [ƶ r θ dʒ tʃ]. The value, however, for [n] to [l] is .67. This is the highest value within the table.

Forming High Correlation Groups. The correlation coefficients were used to group sounds so that all sounds in a given group are highly correlated and each sound is in at least one group. These will be presented in the form of sound graphs which were formed to display pattern similarity. Viewing the graphs, one may observe that similarities in graph patterns improve as the correlation of the grouped sounds to hearing loss improves. In particular, note the similarity of graphs in Figure 21 and Figure 22. For the sounds in each of these two groups, observe their high correlation with hearing loss. This is a new grouping of consonant sounds, heretofore unmentioned in literature.

These graphs will be presented in a slightly different manner than those preceding. The graph will be presented with the correlation tables placed in the left hand portion of the figure.

Figure 21

-d; -p; =t; -k.

CORRELATION MATRIX				
	d	p	t	HL
d				.54
p	.58			.44
t	.60	.55		.60
k	.57	.61	.61	.51

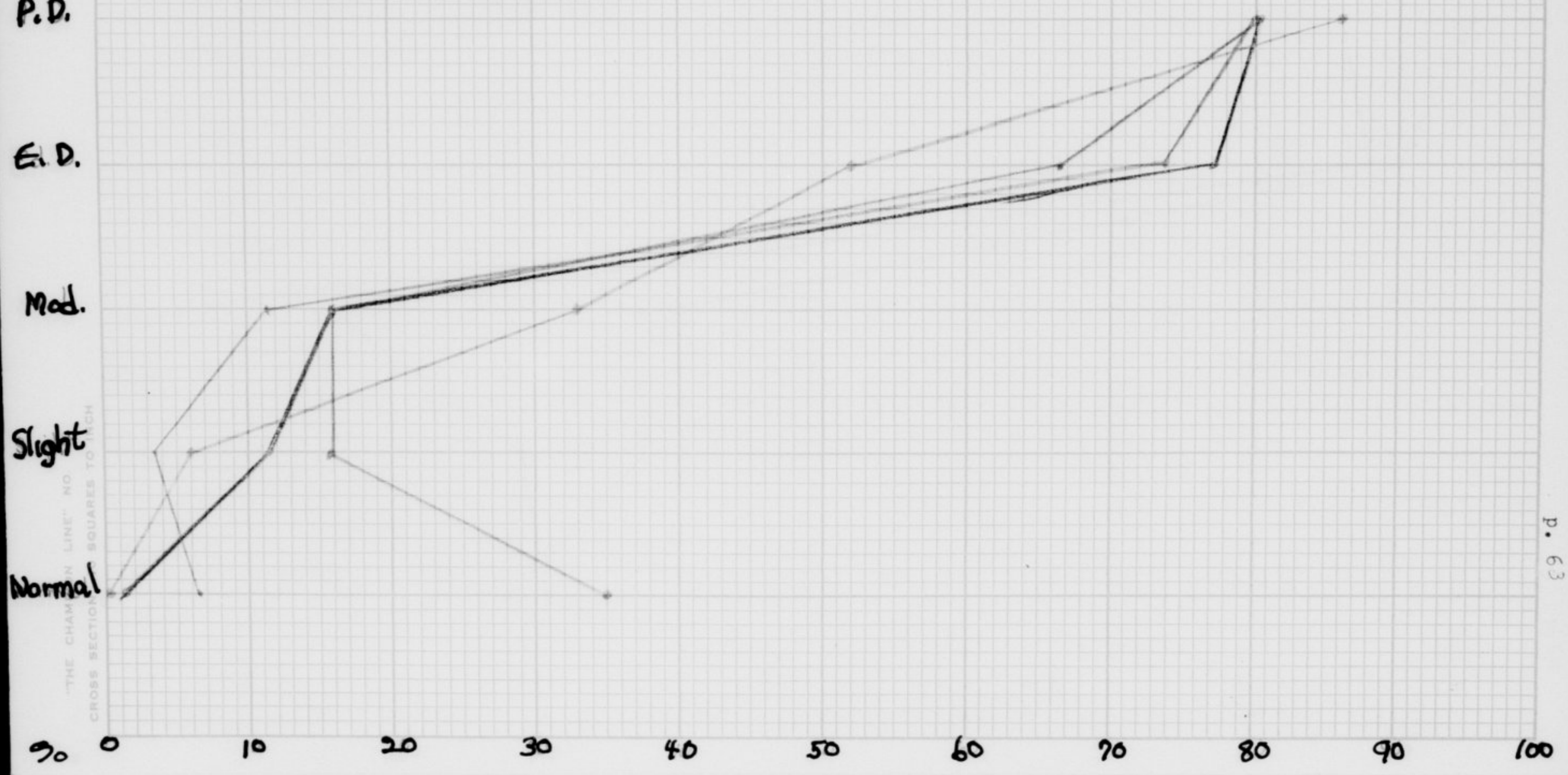


Figure 22

CORRELATION MATRIX

	r	k	g	HL
r				.57
k	.45			.51
g	.61	.57		.53
+∫.	.47	.53	.47	.36

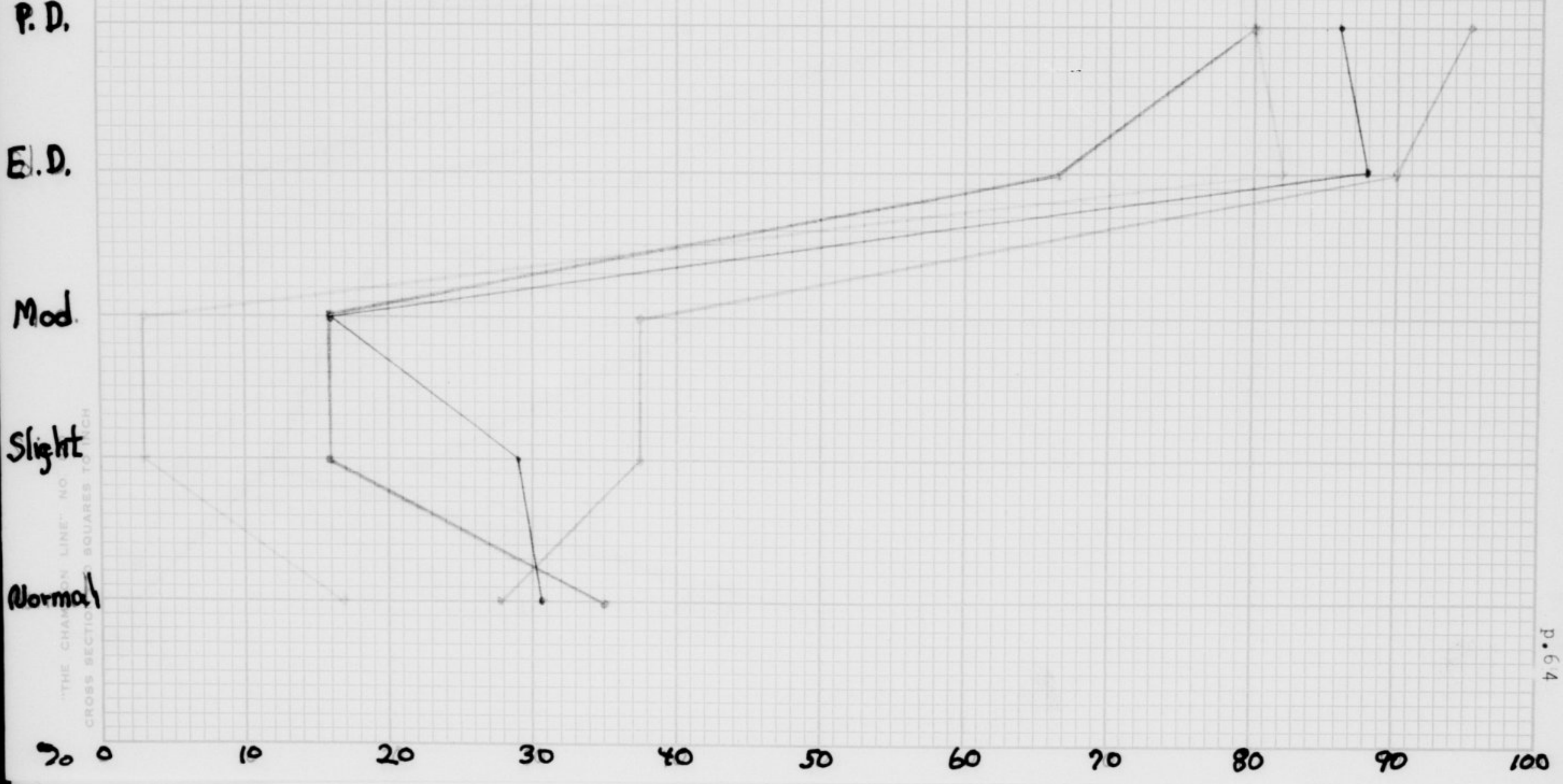
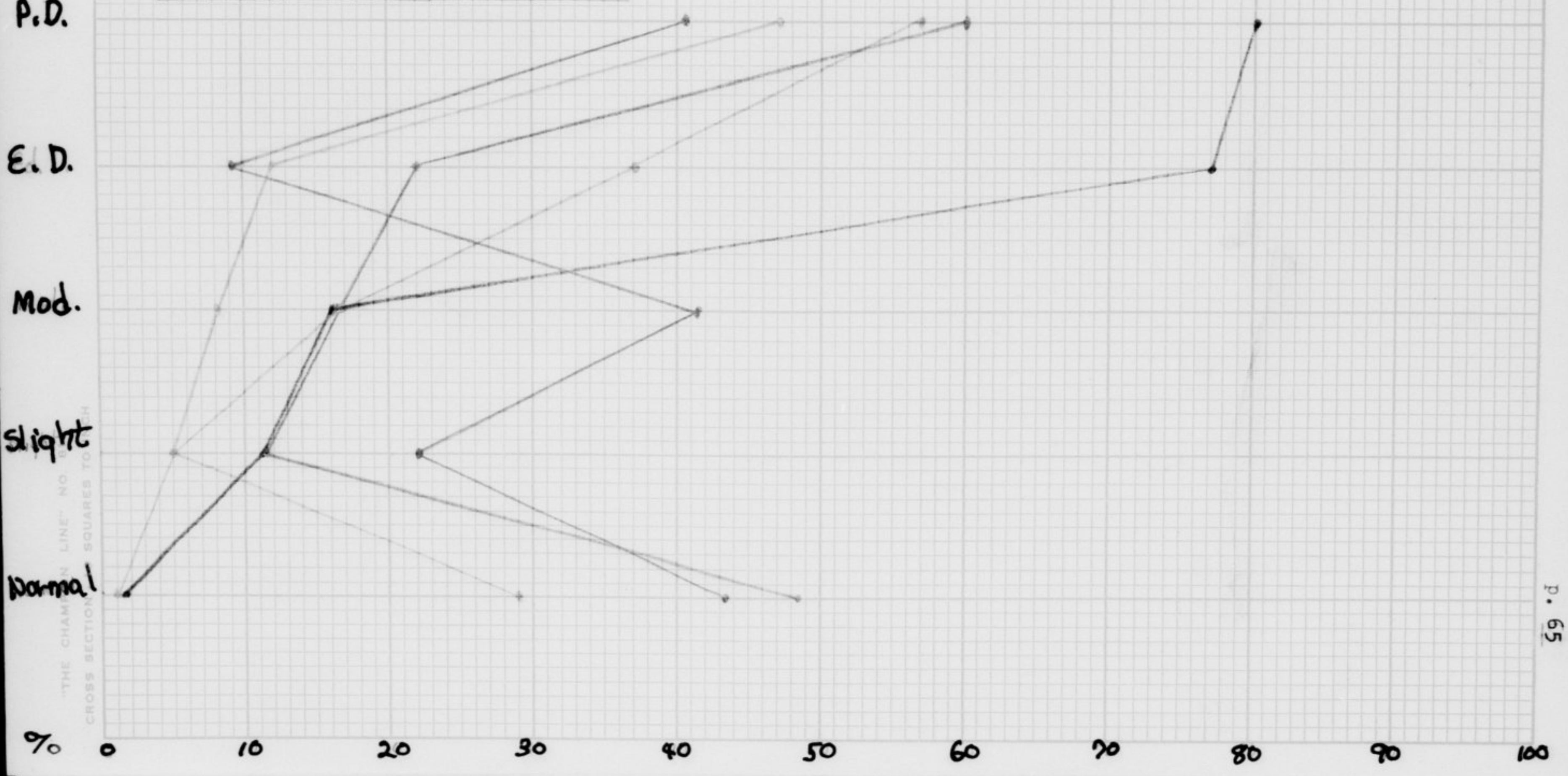


Figure 23

- l; -ƒ; --f; b; p.

CORRELATION MATRIX					
	l	ƒ	f	b	HL
l					.43
ƒ	.60				.13
f	.70	.50			.36
b	.66	.60	.52		.39
p	.64	.66	.67	.66	.44



CORRELATION MATRIX			
	v	l	HL
v			.24
l	.57		.43
f	.54	.70	.36

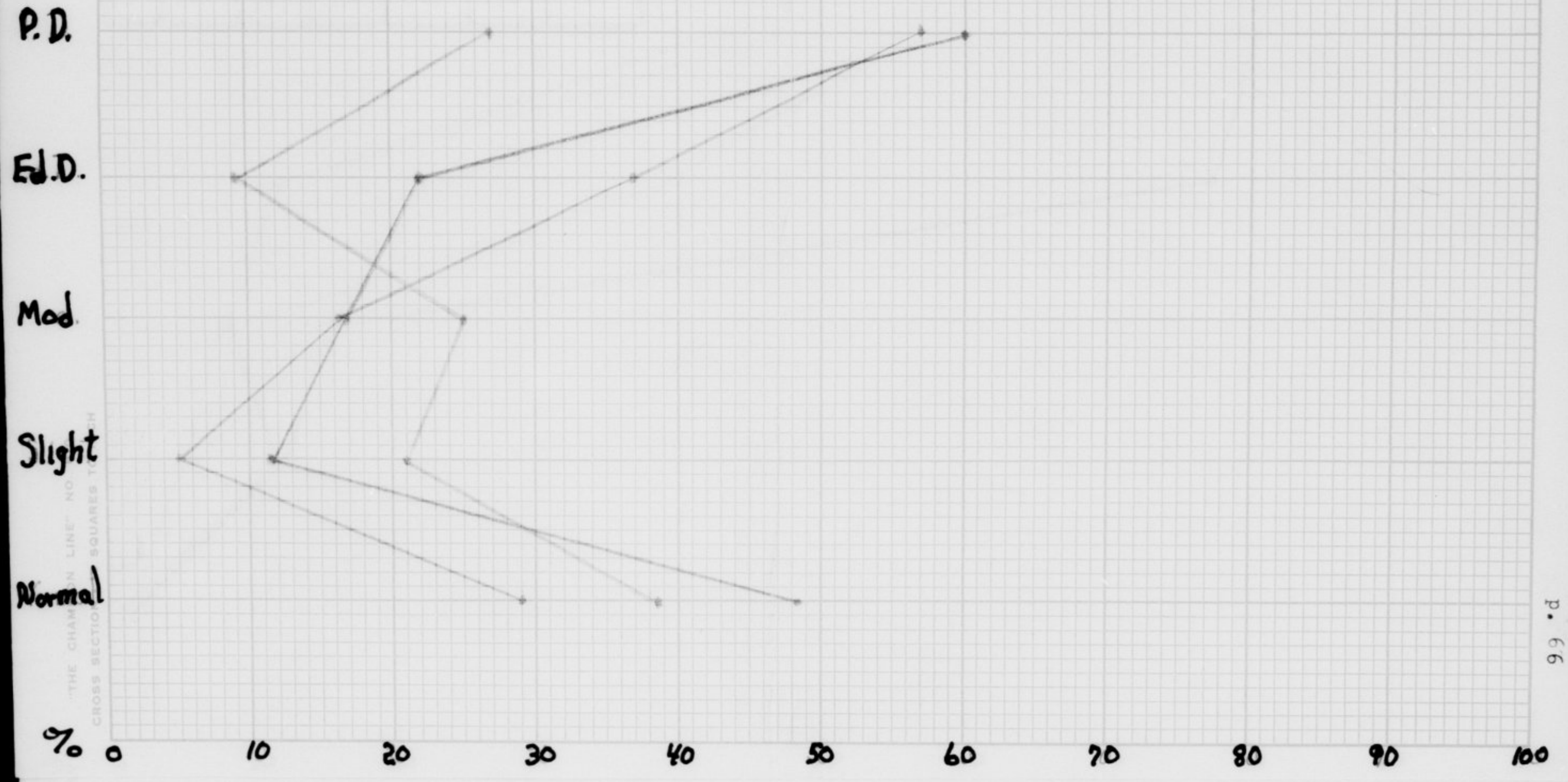


Figure 24

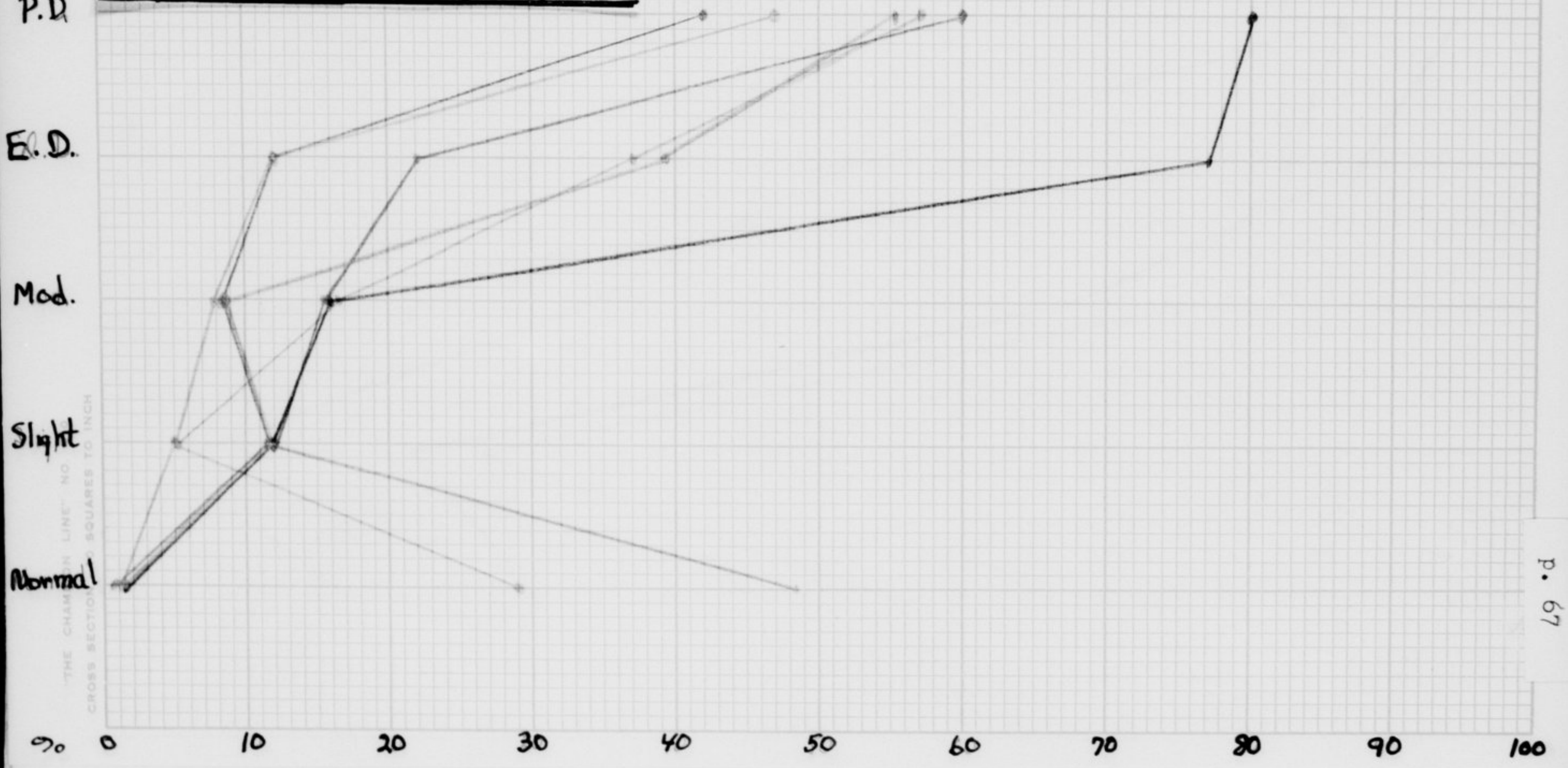
—V; —l; —f

CORRELATION MATRIX

	m	n	p	b	f	HL
m						.49
n	.55					.41
p	.55	.58				.44
b	.43	.56	.66			.39
f	.53	.61	.67	.52		.36
l	.41	.67	.64	.66	.70	.43

Figure 25

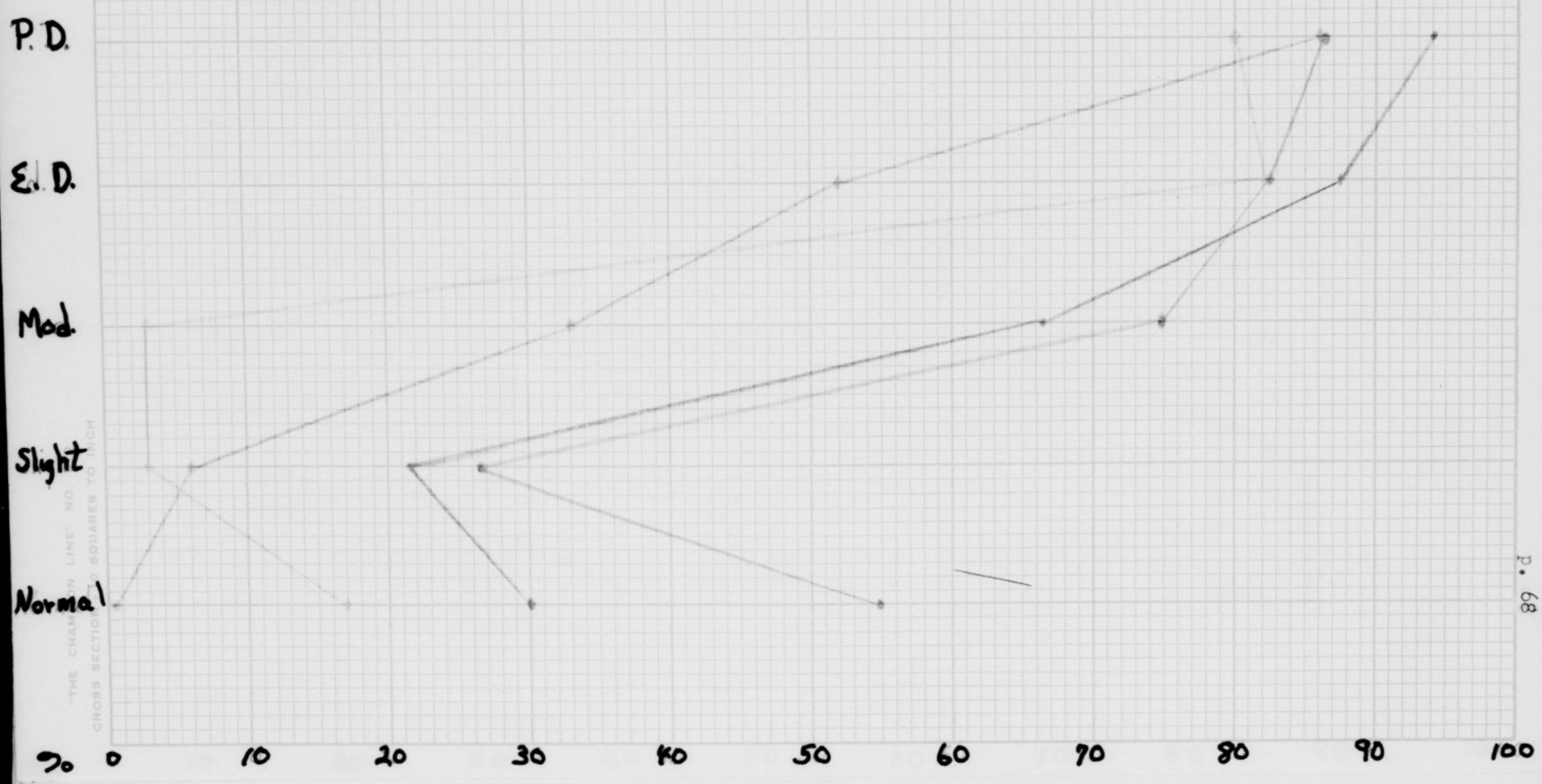
- m; - n; - p; - b; - f; - l.



CORRELATION MATRIX				
	d	g	z	HL
d				.54
g	.65			.53
z	.38	.41		.28
dʒ	.48	.44	.43	.53

Figure 26

— d; — g; — Z; — dʒ.

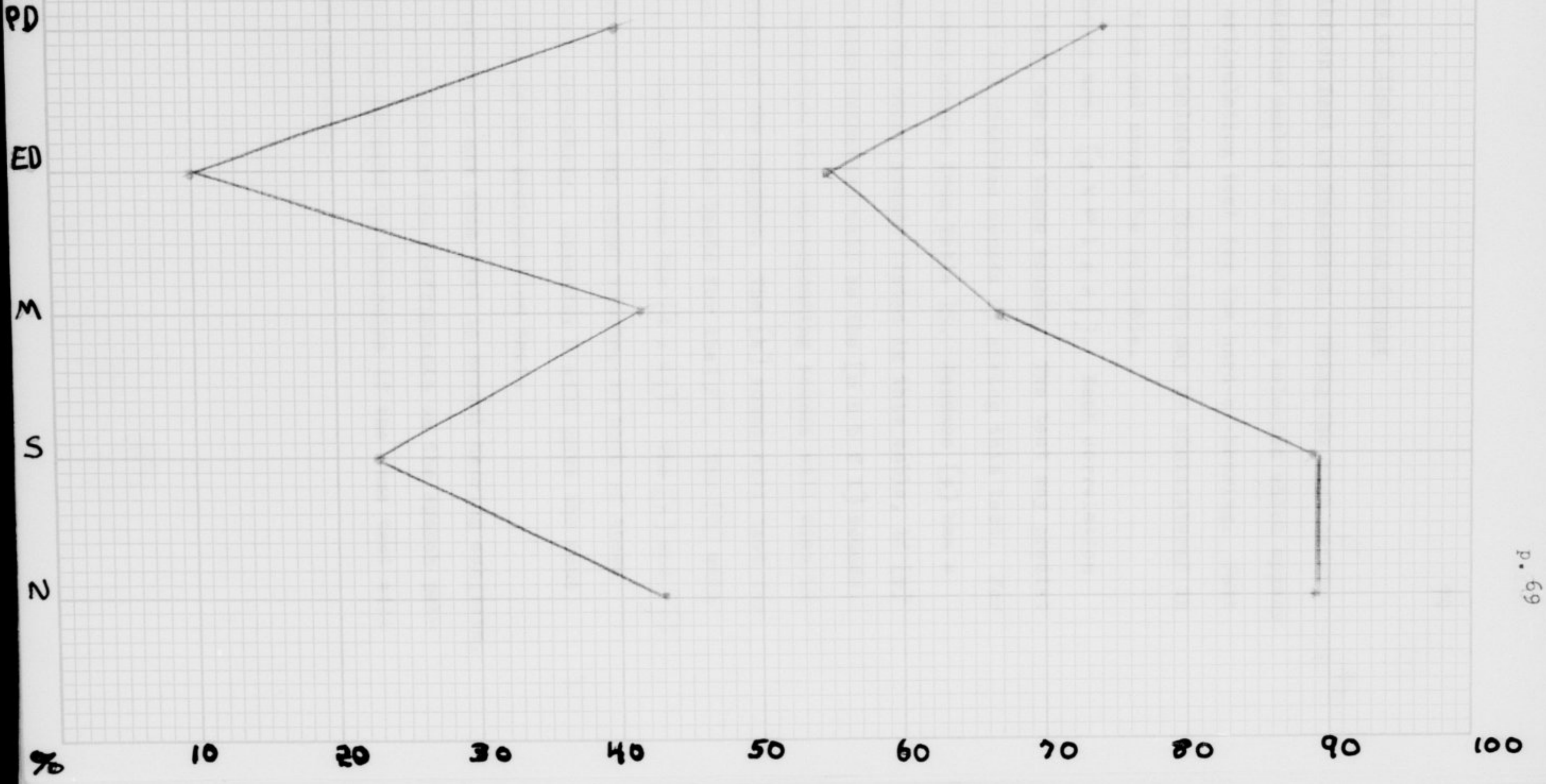


CORRELATION MATRIX

	Θ		HL
Θ			.32
g	.39		.13

Figure 27

-g -Θ



Use of High Correlation Groups

A New Articulation Test is Presented. Using the high correlation groups, a minimum number of sounds are selected which appear sufficient for an articulation test for the hard-of-hearing. Just seven sounds have been included. This test may be administered in a short period of time and should be reliable.

The sounds chosen are: [p k θ l g s ʃ]. Each correlation group contains at least one of these sounds. The test may predict defective sounds for all nineteen sounds by giving this test. For instance, [p] has been chosen from Table 15. Because [p] has a high correlation to the other sounds listed in this table, if [p] is defective, than also defective will be the [m n b f l] sounds. And if [p] is not defective the corresponding sounds will also be correct in the speech of the subject. The [k] sound will test for the [d p t] sounds. The [θ] also tests for the [ð]. The [l] will test for [f b p v ʒ]. The [g] tests for [d z dʒ]. The [s] and [ʃ] do not highly correlate with any other sounds, so both of these sounds must be tested separately. Appendix D will give the word list which may be used in the articulation test.

It may be revealing to use this test in normal hearing subjects. Further study could run correlation coefficients on the speech patterns of normal hearing subjects to determine if the same test will be reliable for all children.

TABLE 4

Percentage of Male and Female Subjects Computed

	Females	Males	% of Males
Normal	16	39	71%
Slight	4	18	82%
Moderate	3	9	75%
Ed. Deaf	13	20	61%
P. Deaf	7	8	54%

Sounds Listed in Order of Difficulty

Table 5, on the following page, lists the sounds in order of difficulty for each of the five groups. These results will be compared with some of the studies mentioned in Chapter IV.

TABLE 5

SOUNDS LISTED IN ORDER OF DIFFICULTY

	Normal	Slight	Moderate	Ed. Deaf	Pro. Deaf
1	θ - 89%	θ - 89%	s - 75%	r - 92%	s - 100%
2	z - 55%	r - 37%	z - 75%	dʒ - 86%	dʒ - 94%
3	s - 52%	s - 34%	θ - 66%	tʃ - 85%	r - 94%
4	l - 46%	ʃ - 34%	dʒ - 62%	s - 85%	tʃ - 89%
5	ð - 42%	tʃ - 29%	ʃ - 41%	z - 82%	z - 86%
6	ʃ - 39%	z - 27%	r - 37%	g - 82%	d - 86%
7	v - 38%	v - 22%	d - 32%	p - 76%	t - 80%
8	k - 35%	ð - 22%	v - 25%	t - 73%	k - 80%
9	tʃ - 31%	dʒ - 21%	ð - 25%	k - 66%	g - 80%
10	dʒ - 30%	k - 16%	tʃ - 21%	ʃ - 65%	p - 80%
11	f - 29%	n - 11%	p - 16%	θ - 55%	ʃ - 78%
12	r - 28%	l - 11%	t - 16%	d - 39%	θ - 74%
13	g - 17%	m - 11%	k - 16%	n - 37%	l - 60%
14	t - 4%	p - 11%	l - 16%	f - 21%	f - 57%
15	p - 2%	g - 6%	f - 16%	l - 20%	n - 53%
16	b - 2%	d - 6%	b - 8%	v - 20%	b - 42%
17	n - 1%	b - 5%	m - 8%	ð - 12%	m - 42%
18	m - 1%	f - 5%	n - 8%	m - 9%	v - 27%
19	d - 0%	t - 2%	g - 6%	b - 8%	ð - 27%

CHAPTER IV

CONCLUSION

This chapter compares the results of this study with some previous studies reported on in Chapter I. Possible implications of this study will be revealed with suggested areas for further research. A brief summary of the study will conclude this thesis.

Some Previous Studies are Compared with this Thesis

As early as 1936 Kerridge[1] made some rather specific statements about the speech of the hard-of-hearing. Two studies by Hudgins and Numbers,[2] and Harriet Green[3] further described the speech of the hard-of-hearing. Parts of their analysis and procedure are similar to those of this study. In 1955 Jacques Penn[4] published another significant study on specific speech deviations in hard-of-hearing subjects. For the sake of clarity, aspects of these studies will be reported and compared with some of the results of this thesis.

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[1] Phyllis Kerridge, "Hearing and Speech and Deaf Children," Proceedings of the Royal Society of Medicine, XXX (May, 1937), 1494-1511.

[2] C. V. Hudgins and Fred Numbers, "An Investigation of the Intelligibility of the Speech of the Deaf," Genetic Psychology Monographs, XXV-XXVI (May, 1942), 289-375.

[3] Harriet Green, "A Study of Speech of the Hard-of-Hearing in the New York City Public Schools in Order of Frequency." (unpublished Master's thesis, Brooklyn College, 1940), 1-46.

[4] Jacques Penn, "Voice and Speech Patterns of the Hard-of-Hearing," Acta Oto-Laryngologica, Supplementum 124, 1955), 1-69.

P. M. T. Kerridge.[1] In 1936 Kerridge made some of the first observations regarding the specific relationship of speech to hearing loss after examining the speech and hearing of 405 deaf subjects attending schools for the deaf. She reported that in the 80+db. group, over 80% had extremely poor speech in spite of years of special speech training and regardless of intelligence. This result is generally confirmed by the regression line for the scatter diagram of Figure 3 (p. 33) of this paper. The percentage of speech errors increases as the age of the subject increases and poor speech occurs at approximately age eleven rather than age thirteen.

Harriet Green.[2] In a study of fifty hard-of-hearing children in the New York Public School System Harriet Green reported the most common errors in articulation were omission of final consonants; confusion of the surd-sonant sounds; substitutions; and implosive plosives. The findings of this paper generally substantiate the Green thesis. Miss Green also reported a difference in the speech pattern when there was a difference in the type of audiogram. For instance, she reports that her 21 db. - 40 db. group with high frequency loss had no normal speech. Every subject in this group had a defective [s] sound. She further reported no normal speech in her group of 40 db. - 60 db. subjects with major loss in the speech range. Miss Green also reported that high frequency hearing losses have the greatest effect on adequate speech production

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[1] Phyllis Kerridge,"Hearing and Speech."

[2] Harriet Green, "Speech of the Hard-of-Hearing."

and that the primary loss in the speech range is the second most damaging to speech. The results of this paper do not conform with those of Miss Green. The correlation table (Appendix C) revealed that high frequency loss and speech range loss were highly correlated and they appeared to be measuring the same things. The discrepancy in the results is probably due to the minimal number of subjects in Miss Green's analysis. The 20 db. - 40 db. high frequency group had fewer than ten children. The 10 db. - 60 db. speech range loss group (where she reported no normal speech) had three children.

The Green thesis is concluded by listing the speech sounds in order of difficulty for the fifty hard-of-hearing subjects as: [ð r s dʒ t θ ʃ tʃ] respectively. Table 5 of this paper reveals that [s r tʃ dʒ] will most often be affected by hearing loss. The two results do not, however, agree regarding the [ð θ tʃ t z]. Regional dialect could possibly account for the discrepancy.

<u>Hudgins and Numbers.</u>[1] The method of testing in the Hudgins and Numbers report differed from the method utilized in this study. Their 192 subjects were from schools for the deaf and the speech of each subject was recorded on a phonograph record. Some general areas for study of the consonant sounds were revealed. They report confusion of the surd-sonant sounds; substitutions; non-function (omission) of the arresting (final) consonant; non-function of the releasing consonant. They listed the consonant sounds in order of difficulty as follows: [d l b h s t z r ʒ ð y ʃ w k m v f tʃ j p θ wh dʒ]. These results do not agree with Miss Green's thesis

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[1] C. V. Hudgins, "An Investigation of Intelligibility."

nor the results of this study. The sentence test (rather than the word test) may effect the results of defective sounds. There would also be some sound distortion in the 1937 phonograph record.

Jacques Penn.[1] Penn conducted a study of one hundred conductive and one hundred perceptive hard-of-hearing male veterans between the ages of 18 and 55 years. Penn reports those with a perceptive loss most often misarticulated the phonemes (.01 level of confidence) [r θ ʒ s l tʃ]. Following with a .05 level of confidence were the [dʒ tʃ ʒ]. Conductive hearing loss groups most often misused [n] and [m]. Those with perceptive losses had, in general, more speech difficulty. The sounds Penn lists as most often defective are quite similar to the ones listed for the slight and moderate subjects of this paper. (Table 5, p. 72). It is probable that the slight-moderate subjects of this paper most resemble Penn's subjects. That is, they have not had speech training nor has a special environment such as a school for the deaf been necessary as a result of the hearing loss. Penn also reports that the sibilants are most often defective in his perceptive group (except for the [z]). This report also reveals this in general to be true. The [dʒ z ʃ s] are all over 50% defective in the moderate hearing loss group. The [tʃ] and [ʃ] are least defective.

Penn notes that in the fricative group the [f] and [v] are most easily made and the [θ] is the most often defective. Results of this paper (Figure 14, p. 50) confirm those results. Penn states hypothetically that the high visibility of [f] and [v] must account

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[1] Jacques Penn, "Voice and Speech of the Hard-of-Hearing."

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[1] Jacques Penn, "Voice and Speech of the Hard-of-Hearing."

for their relatively high scores, since Fletcher[1] reports the fricatives have the lowest acoustic power of all sounds. If hearing ability was the only factor in determining correct production of the fricatives, it appears that all sounds in this group would be equally defective.

Penn reports the [l] and [r] are similarly misarticulated in his hard-of-hearing groups. This was not the case in this study as revealed by Figure 13 (p. 49). This study revealed that [l] was, in every hard-of-hearing group, a great deal less defective than [r]. Perhaps the visual cue (greater for [l] than for [r]) affects the score variability for these two sounds. Penn reports the [m] and [n] are less defective than other sounds. Results of this paper confirm this report. Regarding the [k] and [g] phonemes, Penn reports a slight amount of deviation in the slightly hard-of-hearing groups, with a sharp increase in the distortion of these sounds in deaf groups. This thesis confirms this report (Figure 11, p. 47). Perhaps this sharp rise in sound distortion is due to the tactile and kinesthetic impressions created by the back-tongue velar position which causes the adventitiously deaf to continue to correctly produce this sound. The deaf, on the other hand, have never had the experience of normal production and find it difficult to master. Penn concurs with the study of Green, and Hudgins and Numbers when he lists general categories of deviate speech as omission of final consonants and substitution of one sound for another.

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[1] Harvey Fletcher, Speech and Hearing in Communication (New York: Van Nostrand Company, 1953), p. 91.

Summary, Implications, and Suggested Future Studies

(1) Sounds most often defective for the hard-of-hearing groups were [s r z dʒ tʃ ʃ θ]. It appears to the writer that teaching aids and publications are prolific for the [s l r] and [θ] sounds but are comparatively less on [z dʒ] and [ʃ]. Yet the latter sounds are most often defective in the hard-of-hearing children. Perhaps authors and publishers of speech literature for use in schools for the deaf should increase the amount of literature and teaching aids for the [z dʒ] and [ʃ].

(2) The importance of residual hearing has not been greatly emphasized in current literature. One may be relatively certain that any amount of residual hearing is advantageous to development of speech. This may serve to explain why similar phonemes such as the nasal sounds might show a 25% deviation in the educationally deaf group, with the more visual [m] more often defective than [n]. Residual hearing may account for the large deviation (70%) between [l] and [r] in the educationally deaf. Since all regression lines are not linear with hearing loss, residual hearing may be more important for some sounds than for others.

(3) Distortion of the [θ] does not correlate with hearing loss. Often the speech pathologist begins work on the correct production of the [θ] because it occurs relatively early in speech phoneme development; it is easy to see, therefore easy to teach; and it has been generally supposed that if one could adequately discriminate auditorially between [θ] and other sounds, further sound discrimination would be easier to master.

The results of this paper, however, reveal the hard-of-hearing groups are correctly producing this sound more consistently than the normal hearing groups. In turn, the slights and moderates produce this sound more consistently than the normal hearing groups. This is not the direct proportional speech-hearing relationship which is to be expected. It may be that the school for the deaf groups make this sound more consistently because it has been taught in special speech classes. This speculation, however, would not hold true in the slight and moderate groups which have not had special speech training. It may be that auditory discrimination is not as important in production of [θ] as was once supposed.

Table 5 (p. 72) reveals the [θ] defective in normal hearing speech defective children 89% of the time. The author speculates that the f/θ substitution (as well as the d/θ) is in many areas a part of regional dialect. Further, it may be found that a vast majority of the entire school population is using this sound incorrectly. Hence to that population, the absence of [θ] is not a serious problem. The therapist may decide, then, to postpone correction of [θ] until the more culturally handicapping defects have been corrected. It appears that writers and publishers of speech literature should refrain from producing so much [θ] material.

(4) There has been general agreement that there are three natural groupings of consonant sounds: (a) Surd-sonant; (b) site of placement; (c) manner of articulation. Using the correlation

table, one may speculate that there are other significant properties that generate different groups of consonant sounds which have not been described in literature. Another area for research would be to discover the common factors for the groups of consonants revealed in Figures 21-27 and to determine why the [s] and [ʃ] do not correlate with any of the other consonant sounds.

(5) Finally, a new articulation test (Appendix D) has been presented based on the results of the correlation coefficients. One may theoretically use this short test in order to get an estimate of a hard-of-hearing subject's speech. A further study would be to use the test to determine if the theory holds with another sample group.

The objectives of this descriptive study were to compare the speech patterns of normal and hard-of-hearing children in order to further describe the relationship of these two groups; to survey the literature to determine what group comparisons had already been made; to make some positive statements which would further describe this relationship; and to put these statements to some use in the field of speech and hearing pathology. A total of one hundred thirty four subjects were used in the study. An audiogram and speech analysis were secured for each subject. Subjects were divided into five groups: Normal hearing; slight hard-of-hearing; moderate hard-of-hearing; educationally deaf; and profoundly deaf. Sound graphs were formed which revealed the percentage of subjects in each group that had a particular sound defective. These sound graphs were grouped according to site of placement and manner of formation.

In addition, a computer was used to determine the correlation coefficients of 23 variables in the four groups with the hard-of-hearing subjects. As a result of the Fortran program output, new sound graphs were formed, suggesting there may be another consonant grouping in addition to site of placement, manner of formation, and surd-sonant phonemes.

Scatter diagrams with regression lines were presented which described the relationship between a phoneme and hearing loss. Finally two tables were presented: one which computed the percentage of males and females who have hearing loss; the other lists the sounds in order of difficulty for each of the five groups.

After the results of this study were revealed they were compared with the results of some earlier studies in the field of audiology. Some implications of the study were revealed, including a sample articulation test which theoretically could be used in testing the speech of hard-of-hearing and deaf subjects. It was the intent of this study to contribute theoretically and progmatically to the field of speech and hearing pathology.

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APPENDIX A

THE ARTICULATION TEST

The Bryngelson-Glaspey Word List

s	sun, bicycle, bus
v	valentine, davenport, stove
k	cat, chicken, milk
g	gun, wagon, pig
ʃ	shoe, washing machine, fish
tʃ	chair, pitcher, watch
f	fork, telephone, knife
dʒ	jacks, soldier, orange
l	lamb, balloons, ball
θ	thumb, toothbrush, mouth
z	zipper, scissors, nose
r	red, barn, car

Additional Words Added by the Examiner

d	dog, Indian, hand
ð	the, feather, clothes
m	mouse, ice cream, lamb
b	ball, baby, tub
t	test, letter, cat
p	puppy, airplane, grape
n	nest, pencil, moon

APPENDIX B

SAMPLE TEST SHEET

NAME:________________________ AGE_______

SCHOOL: VSD__________ PUBLIC_______

SPEECH RANGE LOSS:________ RIGHT EAR________ LEFT EAR:_____

AUDIOGRAM

	250	500	1000	2000	4000	8000
0						
20						
40						
60						
80						
100						

O = right ear

x = left ear

Speech Range Loss is average of 500, 1000, 2000

SPEECH ANALYSIS

	j	w	r	l	n	m	b	d	g	p	t	k	z	ʒ	v	ð	s	ʃ	r	θ	dʒ	tʃ
I																						
M																						
F																						

I = Initial position of word

M = Medial position of word

F = Final position of word

\- = omitted sound

In sample above w is substituted for r in the initial,medial positions; r is omitted in the final position

APPENDIX C

23 x 23 MATRIX

	SRL	r	l	n	m	b	d	g	L	HFL
SRL										
r	.57									
l	.43	.17								
n	.44	.18	.67							
m	.49	.35	.41	.55						
b	.39	.12	.66	.56	.43					
d	.54	.47	.41	.42	.53	.38				
g	.53	.61	.35	.26	.54	.34	.65			
p	.44	.32	.64	.58	.55	.66	.58	.46		
t	.60	.39	.49	.50	.41	.47	.60	.47		
k	.51	.45	.48	.48	.54	.41	.58	.57		
z	.28	.41	.24	.08	.34	.26	.38	.41		
v	.24	.04	.57	.37	.34	.47	.25	.29		
ð	.13	.14	.60	.41	.24	.60	.24	.12		
s	.32	.33	.30	.30	.37	.16	.32	.39		
ʃ	.28	.33	.36	.29	.19	.20	.42	.33		
f	.36	.21	.70	.61	.53	.52	.38	.42		
θ	-.32	-.10	.20	.05	-.01	.19	.05	-.04		
dʒ	.53	.36	.21	.19	-.38	.22	.48	.44		
tʃ	.36	.47	.14	.16	.28	.16	.31	.47		
TE	.60	.56	.68	.61	.67	.61	.73	.70		
LFL	.19	.53	.40	.38	.53	.36	.56	.53		
HFL	.89	.60	.30	.33	.31	.24	.42	.48	2	

C

TRIX

	d	g	p	t	k	z	v	ʒ	s	ʃ	f	θ	dʒ	tʃ	TE	LFL	HFL
38																	
34	.65																
66	.58	.46															
47	.60	.47	.55														
41	.58	.57	.61	.61													
26	.38	.41	.37	.28	.30												
47	.25	.29	.38	.31	.27	.08											
60	.24	.12	.66	.30	.31	.32	.35										
16	.32	.39	.28	.42	.37	.21	.20	.14									
20	.42	.33	.34	.43	.36	.33	.30	.40	.37								
52	.38	.42	.67	.49	.58	.32	.54	.50	.40	.26							
19	.05	-.04	.22	.04	.00	.14	.21	.39	.00	.25	.15						
22	.48	.44	.40	.40	.42	.43	.10	.21	.21	.36	.29	-.04					
16	.31	.47	.37	.31	.53	.40	.20	.17	.23	.48	.22	.04	.37				
61	.73	.70	.78	.72	.75	.56	.51	.56	.53	.62	.72	.23	.57	.57			
36	.56	.53	.44	.58	.49	.30	.20	.12	.35	.30	.34	-.26	.55	.35	.60		
24	.42	.48	.36	.54	.46	.27	.15	.08	.35	.31	.31	-.31	.41	.47	.52	.82	

APPENDIX D

NEW ARTICULATION TEST

p	puppy, cup
k	cat, chicken, milk
θ	thumb, toothbrush, teeth
l	lamb, balloons, ball
g	gun, wagon, pig
s	sun, bicycle, bus
ʃ	shoe, washing machine, fish