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The effects of time-altered speech on the auditory discrimination ability of aphasics

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THE EFFECTS OF TIME-ALTERED SPEECH ON THE AUDITORY DISCRIMINATION ABILITY OF APHASICS

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CHAPTER I

INTRODUCTION

Language performance is a unique human function that can be disrupted by damage to the brain. The language disturbance which can result from brain damage is termed aphasia. Aphasia, is a disturbance of language comprehension and usage of a previously acquired language system. Schuell and Jenkins (1972) define aphasia as a . . .

> . . . reduction of language resulting from brain injury, which cuts across various language modalities, such as comprehension of spoken language, speech . . . and upon which specific perceptual, motor or sensori-motor deficits may or may not be superimposed. (1972, p. 5).

Ostfeld (1967) has noted that strokes are a leading cause of death and disability in the United States. They are third in frequency as a cause of suffering in this country, preceded only by heart disease and cancer. Approximately 200,000 new strokes occur per year and Ostfeld (1967) considers this statistic a conservative number. As a result of the strokes, there presently are over two million people in the United States who are disabled and unemployable. (Karpman, Kalb, & Shepard, 1972). Two-thirds of the stroke patients are under the age of sixty-five, and after the onset of a fixed stroke it has been found that rehabilitation is often extremely difficult. (Gordon & Kohn, 1966). Speech pathologists are still uncertain as to how to deal with the language disturbance. This disturbance obviously poses a serious problem for the patient. Therefore, any condition which may help the aphasic to better understand language must be considered a worthwhile area for study.

It has been suggested by Luria (1958), Beyn (1958), and Karasseva (1972), that the aphasic individual's difficulty in understanding and using speech may stem from perceptual disturbances which in turn affect his ability to communicate. Confronted with a series of auditory stimuli, the aphasic frequently has difficulty interpreting the stimuli meaningfully. (Huber, 1944; Winchester & Hartman, 1955; Stoudt, 1964). If the aphasic has difficulty interpreting the auditory stimuli meaningfully, he is obviously going to have difficulty understanding speech.

Clinical reports have indicated that aphasics often have difficulty responding to rapidly presented stimuli. Schuell, Jenkins and Jimenez-Pabon (1964) have noted that people frequently talk too rapidly for the aphasic to understand. They conjectured that one should manipulate the duration of the auditory stimulus so that it becomes easier for the aphasic to perceive it.

Research has indicated that various parameters of time, such as onset, duration and cessation of production, are important dimensions of language. Lenneberg (1967) maintains that language disorders of the central nervous system, such as aphasia, may be characterized as disorders of timing on the part of the listener. Studies (Efron, 1963b; Edwards & Auger, 1965; Ebbin & Edwards, 1967; Brookshire, 1972) have shown that timing factors play a major role in the auditory sequencing ability of aphasics. This auditory sequencing ability has been demonstrated to be disturbed within the aphasic population. These studies, however, have dealt with the timing of the interstimulus interval, and not with the duration of the entire auditory stimulus, which Schuell, Jenkins and Jimenez-Pabon (1964) believed should be manipulated.

Two recent studies (Parkhurst, 1971; DiCarlo and Taub, 1972) altered the duration of the speech stimuli, by means of an Electro Rate Changer, in an effort to measure comprehension ability of aphasics. Results indicated that the experimental conditions (compressed and extended) led to poorer comprehension scores. Parkhurst did note that expansion produced behaviors which indicated that the aphasics may benefit when given more time to process the stimuli. These studies dealt with the comprehension of meaningful stimuli.

The Parkhurst (1970, 1971) observation that aphasics may benefit from extended speech stimuli should be studied further. If differences in the aphasics ability to process speech which had been time-altered were to be found, this information could greatly add to the rehabilitation techniques needed for aphasia treatment.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter presents information on aphasic auditory abilities, with specific reference to the following areas:

(1) time-altered speech;

(2) auditory sequencing ability of aphasics;

(3) auditory discrimination ability of aphasics; and,

(4) auditory perceptual disturbances caused by lesions in the left temporal lobe.

Information will also be presented on the role of distinctive features in speech perception. Finally, the statement of the problem will be posed.

Time-altered Speech

Schuell, Jenkins and Jimenez-Pabon (1964) noted that frequently people talk too much or too rapidly for the aphasic to comprehend. To some aphasic patients, people do not seem to be "talking right" and often times they do not appear to be speaking the correct language. Schuell, Jenkins and Jimenez-Pabon believed that one must manipulate the duration of the auditory stimulus so that the patient could perceive it. They found that:

> . . . patients with perceptual problems are often able to respond more adequately when a word or phrase is spoken a little more slowly than in ordinary conversational speech. However, inflection should be natural,

> and the slowing should not fragment or distort the language unit. (1964, p. 340).

Numerous studies have examined how both listeners with normal hearing and individuals with various audiological pathologies perceive both compressed and extended speech as compared to speech presented at normal rates. Luterman, Welsh and Melrose (1966) presented CID test W-22 word lists that were compressed and extended by 10 and 20 per cent, to young normals, young hard of hearing subjects with sensori-neural losses, and "aged" hard of hearing subjects. Results revealed that both compression and expansion increased the number of errors that occurred, but there was no relationship between age and rate. The amount of compression and expansion in this study was relatively small compared to that used in other studies.

Calearo and Lazzaroni (1957) found that among subjects with temporal lobe lesions, discrimination ability was clearly worsened when an accelerated message was presented. Sticht and Gray (1969) noted that aged subjects had more difficulty than younger subjects, in understanding a message, when compression was increased. This finding was in contrast to that of Luterman, Welsh and Melrose (1966). However, it should be noted that Sticht and Gray (1969) used compressions of 36, 46 and 59 per cent as compared to 10 and 20 per cent used by Luterman, Welsh and Melrose (1966).

In 1969, Foulke and Sticht reviewed the literature on compressed speech. The studies they reviewed indicated that regardless of the compression required, a rapid decline in comprehension commenced beyond a word rate of approximately 275 words per minute. When the word rates were slower than 275 words per minute, only slight or insignificant decreases in comprehension occurred. The studies reviewed, however, involved literary presentations and consequently one has little knowledge of what would happen to the intelligibility of word pairs which have been time-altered. Furthermore, very few studies have attempted to determine what effect time-altered speech has on aphasics.

Parkhurst (1970, 1971) used a modified form of the Token Test to investigate the relationship between the rate of a spoken command and how accurately the aphasic can execute the command. She found that the aphasics performed poorest when speech was compressed and performed about the same under the normal and extended conditions. Speech was compressed by 32 per cent and extended by 37 per cent. She did note, however, that ". . . expansion produced behaviors that suggest that the aphasic might benefit when given more time than usual to process the first part of a long speech stimulus." (1970, p. 6).

In 1972, DiCarlo and Taub used 20 young adult aphasic and 20 aged adult aphasic subjects to measure the intelligibility of words in a single control condition, two conditions of extended speech (30 and 50 per cent), and two conditions of compressed speech (30 and 50 per cent). Their results indicated that both groups performed more poorly in the experimental conditions, and that compression led to greater losses than expansion. Furthermore, they noted that the young adult aphasics performed better than the aged subjects in all conditions. It is apparent, then, that the rate of the stimulus presentation does affect the ability to process information.

Auditory Sequencing Ability of Aphasics

Investigators have also studied the role that time plays in the comprehension of language. Lenneberg (1967) proposes that aphasia is a difficulty in temporal sequencing. He maintains that most speech and language disorders of the central nervous system can be characterized as disorders of timing on the part of the listener; timing factors in the sense of ". . . onset, duration, and cessation of voice." (1967, p. 97). He further states that ". . . failure to understand may well be due to certain time-disorders in the hearer." (1967, p. 219).

The relationship between auditory temporal disorders and adult aphasia has been well documented, (Efron, 1963a, 1963b; Edwards and Auger, 1965; Brookshire, 1972). Efron (1963a) demonstrated that the ". . . comparison of the time of occurrence of any two sensory stimuli requires the use of the hemisphere which is dominant for language functions." (1963a,

p. 283). Efron (1963b) then attempted to limit further the areas of the brain involved in such an ability, to those areas affected in aphasia. He examined sixteen subjects: eleven subjects with left hemisphere lesions and aphasia, one subject with a left hemisphere lesion and no aphasia, and four subjects with right hemisphere lesions in the same general area and no aphasia. Subjects performed both a visual and auditory sequencing task. In the visual task, the subjects had to indicate which of two different colored lights appeared first. In the auditory task, the subjects had to indicate which of two tones, differing in frequency, came first. Results showed that ". . . every subject with a dominant hemisphere lesion who had difficulty with temporal analysis also had some degree of aphasia." (1963b, p. 407). In other words, aphasics had more difficulty than normals and brain damaged nonaphasics in both tasks. An unexpected result was that those aphasics classified as expressive aphasics performed more poorly on the auditory task than on the visual one; whereas, those classified as receptive aphasics had more difficulty with the visual task than with the auditory task. This indicates that even predominantly expressive aphasics may have impaired auditory temporal perception.

In 1972, Brookshire attempted to investigate the auditory and visual sequencing abilities of aphasics further. He compared their performances with those of nonaphasic, non-brain damaged subjects on the same task. The results of his study supported Efron's (1963b) finding that "expressive" aphasic subjects have more severe auditory sequencing deficits than the "receptive" aphasic subjects, ". . . even though they [expressive aphasics] have less difficulty understanding speech." (1972, p. 268).

Edwards and Auger (1965) compared the performance of aphasic, nonaphasic brain damaged, and normal subjects on a "precedence" task that was similar to Efron's (1963b). Subjects had to determine which of two tones, differing both in loudness and frequency, came first. The time interval between the tones varied. Results indicated that aphasics performed significantly poorer than the other two groups in determining which tone came first. If the tones were seperated by enough time, however, the aphasics could sequence the tones correctly.

These studies can be interpreted as indicating that the rate of stimulus presentation can affect the ability to order tones accurately, and that aphasics require more time, (i.e. a slower rate of presentation), to order tones than do nonaphasics. Aaronson (1967) has noted that:

> . . . Increasing the presentation rate of the stimulus sequences, which restricts the time available for perception between items, frequently results in poorer recall accuracy. It appears that the physical stimulus duration per se is not a crucial factor in determining recall accuracy. Instead, the critical factor is the time during which the stimulus information is available

> to the subject for perception, which may be longer than the physical stimulus duration. (1967, p. 142).

Carson, Carson, and Tikofsky (1968) suggest that aphasics process information in a similar manner to nonaphasics. The only difference being that aphasics exhibit slower information handling. It is this slower information handling that may result in the poorer auditory discriminating abilities by the aphasic as compared to the nonaphasic.

<u>Auditory Discrimination Ability of Aphasics</u>

Huber (1944) investigated auditory discrimination in a single case of "Wernicke's aphasia." She constructed six tests that included vowels, consonants, monosyllabic, and disyllabic words. She had the subject respond by repeating the stimulus items which she in turn recorded phonetically. She observed that there were a greater number of correct responses on the simpler sound combinations such as the monosyllabic words that included only voiced consonant sounds. This suggested ". . . that the subject's difficulties were predominantly those of perception rather than initiation [production]." (1944, p. 236). She further noted that at the phonemic level, voicing or unvoicing of a given sound did not appear to influence the correctness of the response. However, voiceless consonants were more frequently missed than voiced consonants when presented in words.

Winchester and Hartman (1955) looked at the aphasic's ability to discriminate in the presence of noise. They were interested in the evaluation of "auditory dedifferentiation." The term dedifferentiation was suggested to ". . . designate a breakdown in the ability to distinguish between the 'foreground' and the 'background' of a given sensory, motor, or ideational configuration." (1955, p. 178). Brain injured and non-brain injured subjects were presented with two auditory discrimination tasks. The first consisted of thirty-four familiar and concrete noun pairs that were progressively attenuated. The second task was a similar noun pair list that was presented against a constant level of background noise. The non-brain injured group performed equally well in both tasks, whereas, the brain injured group performed significantly better without noise. Their results support the conclusion ". . . that there is a breakdown in the auditory differentiating ability in the brain injured person. . . ." (1955, p. 182).

In 1964, Stoudt evaluated assumptions, concerned with an aphasic's discrimination ability, that were basic to the "phonemic regression" hypothesis of Jakobson (1971). Jakobson suggested that the phonemic production of aphasics shows a regression to infantile speech patterns. He asserted that discrimination difficulty is fundamental to this regression. Stoudt (1964) used the following consonants in making up his lists: /p,t,k,f,s,ʃ,θ,b,d,g,v,z,ð,m, and n/.

Miller and Nicely (1955) have pointed out that these fifteen consonants plus /ʒ/, ". . . make up almost three-quarters of the consonants we utter in normal speech and about 40 per cent of all phonemes, vowels included." (1955, p. 338). The use of these consonants provided Stoudt (1964) with an adequate sample of those used in daily conversation. Stoudt paired each consonant with every other one and with itself, which resulted in 120 sound contrast pairs. He then classified each pair according to the number of Miller and Nicely Perceptual Characteristics (MNPC) between each pair in the initial phoneme. These perceptual characteristics refer to those features of speech production that are reflected in certain acoustic characteristics for discriminating consonants. These are (1) voicing; (2) nasality; (3) affrication; (40 duration; and, (5) place of articulation. These perceptual cues were derived from Miller and Nicely's (1955) study on perceptual confusions among some English consonants. Stoudt's (1964) aphasic and nonaphasic subjects were evaluated in their ability to make discriminations of sound contrasts which had been classified according to the number of characteristic differences between them.

The results indicated that aphasics did not discriminate consonant sounds as well as nonaphasics. Furthermore, both aphasics and nonaphasics were able to discriminate better when the sound contrasts differed by more than one characteristic difference.

In 1967, Ebbin and Edwards undertook a study of speech sound discrimination by aphasic and nonaphasic brain damaged subjects. Subjects were presented with two nonsense syllables and had to report whether the two were the same or different. The syllable pairs were seperated by two different time intervals--200 milliseconds or as little as splicing would allow. Results indicated that aphasics discriminated more poorly than the nonaphasics for both time intervals. Furthermore, the ability of the aphasics to discriminate was significantly impaired when the time between the two speech sounds was shortened.

Research by Luria, 1958, 1966; Beyn, 1958; and Karasseva, 1972, has shown that the aphasic's perceptual disturbances and his ability to make auditory discriminations may be related to lesions of the left temporal lobe.

Auditory Perceptual Disturbances Caused by Lesions in the Left Temporal Lobe

Confronted with a series of auditory stimuli, the aphasic frequently has difficulty interpreting the stimuli meaningfully. The aphasic individual's difficulty in understanding and using speech may stem from perceptual disturbances which may affect his ability to communicate.

Several investigators (Luria, 1958; Beyn, 1958; Karasseva, 1972) hold that auditory perceptual difficulties may be the result of damage to the central nervous system, and more specifically, to the left temporal lobe area. Luria (1958) has shown that a disturbance of auditory perception is a fundamental and persistent, but <u>not</u> exclusive, symptom of left temporal lobe lesions. These lesions do . . .

> . . . not produce any hearing loss for any part of the frequency range, but inevitably lead to damage in the process of differentiation and generalization of sounds, in other words, in the process of sound analysis and synthesis. (1958, p. 17).

Luria further contends that areas adjoining the left temporal lobe may also be affected by the lesion. This may in turn produce a series of secondary disorders such as ". . . the breakdown . . . in the pronunciation of words. . . ." (1958, p. 19). In other words, the lesion that causes the breakdown of the sound analysis and synthesis processes may also be responsible for expressive disturbances.

In 1958, Beyn reemphasized Luria's findings. Basing his conclusions on an investigation of 55 aphasic subjects, he noted that the lesions of the left temporal cortex ". . . greatly disrupt[ed] the analysis and synthesis of speech sounds. . . ." (1958, p. 235).

Karasseva (1972) also tried to establish what role the human temporal lobe has in the perception of single acoustic signals. Using 96 subjects with focal lesions in various portions of the brain, he investigated auditory perception by means of pure tone and speech audiometry. His methods revealed ". . . an impairment of auditory perception which proved to be associated with lesions of the superior part of the temporal lobe; namely a disturbance in the perception of short sounds." (1972, p. 229).

Although these studies indicate that aphasic auditory perceptual disturbances are related to lesions of the left temporal lobe, one cannot conclude that auditory discrimination difficulties are exclusive to left temporal lobe lesions. In fact, Luria (1958, 1966) has observed auditory discrimination difficulties in many aphasics with lesions that are not within the left temporal lobe.

Role of Distinctive Features in Speech Perception

Luria (1970) has suggested that:

> The distinguishing characteristic of human hearing, and particularly of speech hearing, lies not in special acuity or in the range of frequencies which can be heard. . . . Instead, the difference is that human hearing represents a complex system of differentiations which are organized and generalized according to the phonemic system of a given language. Certain sound features are seperated out as specific information carrying cues, phonemes. (1970, p. 110).

Luria (1970) notes that within a given language there are certain features of the acoustic stimuli that are important and some that are not as important in the understanding or meaning of words. These features are ". . . the articulatory and acoustic characteristics of the set of speech sounds of the language." (Menyuk, 1971, p. 21). These characteristics are better known as distinctive features. The speech sounds or phonemes ". . . of which these distinctive features are attributes . . . [are] the basic units of spoken language." (Luria, 1970, p. 108). Furthermore, none ". . . of them can be broken down into smaller linguistic units." (Jakobson, 1971, p. 3). Although distinctive features are important, Jakobson (1971) has shown that the distinctive features for one language may lack significance in terms of meaning in another language.

Distinctive features play a major role in speech perception. Luria (1970) noted that the processing of speech is complex in two respects. First of all, it involves ". . . the analysis and synthesis of complex patterned sound stimuli. . . ." (1970, p. 108). Thus, it is this extraction of essential features and the inhibition of extraneous ones that is the major function of "discriminative speech hearing." The other essential function involved in processing spoken language is the ". . . synthesis and transformation of cues into the constant units of a given language--phonemes." (1970, p. 108). It is the constancy of phonemes, which are based upon the distinctive features of the language, that are such essential characteristics of both expressive and receptive speech.

It is the breakdown in the processing of the spoken language and its distinctive features, that is frequently observed following cortical or subcortical damage in aphasia. Although processing difficulties are frequently observed, speech pathologists are still uncertain as to how to deal with these problems. Therefore, if differences in the aphasics ability to discriminate speech which has been time-altered were to be found, this information could greatly add to the rehabilitation techniques needed for aphasia treatment.

STATEMENT OF THE PROBLEM

The present study was designed to answer the following questions:

(1) what effect does time-altered speech have on the aphasic's ability to discriminate nonsense syllable pairs; and,

(2) is correct discrimination of the syllable pairs positively related to the number of different distinctive features involved, or to the time differences in the time-altered conditions.

It was postulated that the slower the rate of speech, the better the ability of the aphasic to discriminate; and that the number of different distinctive features involved would be positively related to correct discrimination, regardless of the time-altered condition.

CHAPTER III

PROCEDURE

The present study was designed to determine whether time-altered speech (compressed and extended) has any effect on the aphasic's ability to discriminate nonsense syllable pairs; and, if correct discrimination would be positively related to the number of different distinctive features involved, or to the time differences in the time-altered conditions.

Subjects

Ten subjects, ages 32 to 63 years old, were evaluated for possible inclusion in this study. All subjects were male aphasics and were receiving speech therapy at the time of the evaluation.

To be included in the experimental population, subjects had to meet the following criteria:

(1) be a native speaker of English;

(2) be diagnosed as aphasic by a speech pathologist holding the American Speech and Hearing Association Certificate of Clinical Competence;

(3) be a left hemisphere lesion aphasic;

(4) have adequate hearing, which was defined as a 25dB pure-tone average or better at 500, 1000, and 2000

Hertz, for both ears;

(5) be able to respond using a non-verbal response mode employed in this study; and,

(6) be able to accurately discriminate eight out of twelve of the practice nonsense syllable pairs during a maximum of five trials, on two out of three days.

The first criterion was considered necessary to assume uniform experience in making English phonemic discriminations. The second and third criteria were necessary to exclude other communicative disorders from the population. The fourth criterion was necessary to exclude any possible peripheral hearing loss as a factor in the subject's responses. The fifth and sixth criteria were considered necessary to assure performance capabilities on the experimental task.

The final experimental population consisted of six subjects who met the necessary criteria. Of the four subjects who were not used in this study, one had met all the requirements, however, he suffered another CVA the day prior to testing. Of the other three subjects, two were excluded due to lesions of the right hemisphere, and one was excluded due to hearing loss.

The six subjects included in this study were between the ages of 32 and 58 years of age. The median age was 45 and the mean age was 44.2. The number of months post-onset of the lesions were between 4 and 45 months. The median months post-onset was 8 and the mean was 14.8. The lesions of five subjects were the result of a cerebral vascular accident. The lesion of the sixth subject was the result of a traumatic head injury.

In addition to biographical information, current results of the Wepman Test of Auditory Discrimination (1958), the Token Test--Benton and Spreen version (DeRenzi and Vignolo, 1962), and the Porch Index of Communicative Abilities (1967) were available or were obtained. The Wepman Test (1958) was included in order to give some indication as to the subject's ability in auditory discrimination. The Wepman Test is a ". . . short and easily administered test that does not require visual, speech, or reading ability to arrive at its results." (Wepman, 1960, p. 329). The Token Test (1962) was utilized because it examines the receptive language processes in aphasics to ". . . reveal slight disturbances in the understanding of speech, without challenging other intellectual functions. . . ." (1962, p. 677). The Porch Index of Communicative Abilities (1967) was included because of its high reliability and sensitivity for quantifying and describing the characteristics of aphasia.

Group means and the range of percentage-correct scores for the three tests were computed and are reported in Table I. The mean percentage-correct scores for the group were 92.5, 84.6, and 67.0 per cent correct for the Wepman, the Token

TABLE I

GROUP MEANS AND RANGES OF PERCENTAGE-CORRECT FOR THE WEPMAN TEST, THE TOKEN TEST, AND THE PORCH INDEX OF COMMUNICATIVE ABILITIES (PICA)

	WEPMAN	TOKEN	PICA
GROUP MEAN	92.5	84.6	67.0
RANGE	90.0-97.5	64.4-96.9	25.0-91.0

and the Porch Index of Communicative Abilities tests respectively. As further indicated in Table I, intersubject examination revealed that there was a small range (90.0-97.5) in per cent correct scores for the Wepman Test. However, intersubject scores revealed a wide range of difference, in terms of per cent correct scores, for the Token Test (64.4-96.9) and for the Porch Index of Communicative Abilities (25.0-91.0). Individual scores and other biographical information are available in Appendix A.

Stimulus Material

Three types of stimulus material were used in this study: training, practice, and experimental material. These materials are listed in Appendix B.

The training material, which was developed by this experimenter, consisted of two parts. The first part was a set of ten word pairs, such as dog/cat and coat/shoe, that could be discriminated on a semantic as well as a sound contrast basis. The second part of the training material consisted of fifteen nonsense syllable pairs, such as /mik/sik/ and /deib/teib/, that could only be discriminated by making sound distinctions of the initial phoneme. Ten of these pairs were arranged so that they went from maximal (five) to minimal (one) distinctive feature differences, as classified by Miller and Nicely (1955). Intermixed in these ten pairs were five nonsense syllable pairs that had no distinctive feature differences.

The practice material consisted of twelve nonsense syllable pairs that were developed by Stoudt (1964). Stoudt substituted the consonants /dʒ,w,h,l,r,n/ for the initial consonants of words to develop nonsense words, such as /reib/leib/ and /dʒal/ral/.

The experimental material consisted of the three nonsense syllable pair lists developed and used by Stoudt (1964). In constructing the nonsense syllable pair lists, Stoudt took the Word/Word list used in his study and changed ". . . the final consonant of each word pair to produce a nonsense syllable. Thus shed/bed was transformed to /ʃɛm/bɛm/." (1964. p. 31). In producing the nonsense syllables, he used only allowable English phonemic sequences. Stoudt's Word/Word lists were ". . . selected from the Thorndike-Lorge count . . . (and) were balanced with respect to frequency of occurrence." (1964, p. 84). The three nonsense syllable pair lists consisted of 120 nonsense syllable pairs each. An analysis of all possible combinations of consonant contrasts according to the number of Miller and Nicely Perceptual Characteristics (MNPC) is presented in Appendix C. The MNPC or distinctive features used in the experimental material were (1) voicing; (2) nasality; (3) affrication; (4) duration; and, (5) place of articulation.

Recording Process

The practice and experimental material was recorded by a native American-English speaker, who spoke at a steady rate and with normal intonation. The recordings were made in an I.A.C. 400 series, test suite, using a Revox A77 recorder and a Revox High Fidelity microphone. The practice and experimental materials were recorded with approximately a one second interstimulus interval. This material was recorded onto BASF audiotape at 3 3/4 i.p.s., which was the speed dictated by the processing system. All recordings were monitored constantly on the V.U. meter by this experimenter to assure a consistent recording level.

The original (master) recordings of the practice and experimental material were then processed through an LM-312 Pitch Normalizer by means of a Sony-Matic T-104 tape-recorder. The practice material was processed only in the normal condition, so that it would go through the same filtering process as the experimental normal condition. The experimental material was processed so that each list was re-recorded in the compressed, normal rate, and extended conditions. The re-recordings of the practice and experimental materials were recorded on BASF audiotape with a Sony-Matic T-104 tape-recorder at 7 1/2 i.p.s..

Time-alteration

The compressed, normal, and extended rates of the experimental material were all processed through the LM-312 Pitch Normalizer. The practice material was also processed in the normal mode. The LM-312 Pitch Normalizer was developed by the Lockheed Missiles and Space Company, and was on loan to the University of the Pacific.

The LM-312 Pitch Normalizer is an instrument. . .

> . . . which allows expansion to ½ the normal rate or compression by a factor of two. It has banks of narrow bandpass filters, the output of which is either frequency doubled (in the case of expansion) or frequency halved (in the case of compression). For example, in the twice rate mode, a voice spectrum which is normally between 100-3500 Hz is doubled so that it enters the speech processor at 200-7000 Hz.. This spectrum is then presented to thirty-six 100 Hz filters spaced 100 Hz apart. The frequency of the output of these filters is divided by two to correct for the pitch change and the result is then summed in an amplifier and presented to the listeners. (Harris, 1972, p. 1).

In addition to the compressed and extended modes, the LM-312 Pitch Normalizer has a third or normal mode that bypasses the compression and expansion modes; however, it filters the stimuli and makes the frequency spectrum of normal speech the equivalent of the compressed and extended stimuli. This normal bandwidth limited condition will subsequently be referred to as normal rate.

Response Mode

A nonverbal response mode (Appendix D) was used by which the subjects could indicate their responses. The nonverbal response mode consisted of pointing to a drawing of two circles, 4½ inches in diameter, on the left side, and a square and triangle, 4½ inches in width at the base, on the right side of a large (20 inch by 15 inch) piece of cardboard. Along with this, there were two 3 inch by 5 inch cards with the word SAME or NOT THE SAME printed on them. These cards were placed above the appropriate half of the response card and could be used if the drawing was too abstract for the subject.

To indicate a "same" response, the subjects pointed to the two circles or the word SAME. A "different" response was indicated by pointing to the square and the triangle or the words NOT THE SAME.

Subject Instructions

Prior to the presentation of any of the stimuli on a given day, each subject was given the following instructions verbally:

> This is going to be a listening task. I am interested in how you hear speech sounds. I am trying to find out how well you can tell the difference between speech sounds. I am interested in what you think. You are going to hear two words at a time. You must decide if the words are the same or not the same. If the two words sound the same to you, point to the two circles or the word SAME. If the two words sound different to you, point to the triangle and the square or to the words NOT THE SAME. You will only have a short time to decide. If at any time you become tired and want to rest, let me know. Do you understand what you are to do? Are you ready?

During the instructions, the response mode was demonstrated by the experimenter. The subjects were then presented with the appropriate stimuli for that session.

Presentation of Stimuli

All testing was performed in a quiet room with each subject sitting to the right of the experimenter, at a large table. The three types of material were presented each day to all six subjects over a period of three days. First, the training material was presented orally. The presentation of this material served three functions:

(1) provided the experimenter with a gross estimate of the subject's ability to perform the task;

(2) allowed the experimenter to determine which nonverbal response mode the subject preferred; and,

(3) provided the subjects with practice for making dis-

criminations and for using the nonverbal response mode.

Then, the practice and experimental materials were presented.

A counter-balanced design (Appendix E) was used for the order of presentation of the three experimental lists and for the order of conditions. Each list under each condition was divided into three equal segments of 40 nonsense syllable pairs. On day one, the first forty pairs from each list were presented in each condition. On day two, the second forty pairs from each list were presented in each condition; and, on the third day, the last forty pairs from each list were presented in each condition.

The practice and experimental materials were presented on a Sony TC-540 Solid State tape-recorder. This tape-recorder had a built-in pause device that allowed the experimenter to stop the tape after the presentation of each stimulus pair. The tape was restarted after the subject had given his response. This allowed the subject as much time as necessary to make a response. Testing lasted approximately 30 minutes each day.

Each subject heard the material binaurally through a set of KOSS KO-727B stereophones. The experimenter also monitored the stimulus material through a set of earphones, while recording all subject responses for the practice and experimental material on a data sheet.

CHAPTER IV

ANALYSIS OF THE DATA AND DISCUSSION

The purpose of this study was to determine whether compressed, normal rate, and extended speech had any effect on the aphasic's ability to discriminate nonsense syllable pairs. It also examined whether correct discrimination of the syllable pairs was related more to the number of different distinctive features involved, or to the time differences in the three conditions. It was postulated that the slower the rate of speech, the better the ability of the aphasic to discriminate; and, that correct discrimination would be positively related to the number of different distinctive features involved, regardless of time condition.

All subject responses were recorded by this experimenter and then analyzed statistically and for various measures of per cent correct. The raw scores for each subject appear in Appendix F.

Analysis of the Data

The Friedman two-way analysis of variance (Siegel, 1956) was employed to determine if there were any statistically significant differences between:

(1) the time conditions of stimuli presentation and the discrimination ability of aphasics; and,

(2) correct discrimination scores and the number of different distinctive features involved, regardless of time condition.

Examination of the data was also done in terms of percentages. Percentages were used because they illustrate more graphically the differences in discrimination abilities which occurred in the various time conditions, and, in considering the number of different distinctive features involved. This examination was done on both an intersubject and intrasubject basis. Percentage scores for the following were obtained:

(1) total per cent correct for all subjects in each time condition;

(2) total per cent correct for each subject within each time condition; and,

(3) per cent correct for the paired words, including like number of distinctive features, for each time condition.

Table II presents the mean correct scores for the group in per cent for each time condition and the "f" score. A Friedman two-way analysis of variance revealed that there were significant differences between the aphasics' ability to discriminate within the three time conditions. These differences were found to be statistically significant beyond the .001 level of confidence. (Siegel, 1956). The aphasics demonstrated their poorest discrimination scores in the extended

TABLE II

GROUP MEAN PERCENTAGE SCORES FOR

EACH TIME CONDITION AND THE "f" SCORE

	COMPRESSED	NORMAL RATE	EXTENDED	
MEAN PERCENTAGE	66.25	87.22	51.95	
"f" SCORE				41.58*

* Significant beyond .001 level of confidence

condition. Better discrimination scores were obtained in the compressed condition, while the highest discrimination scores were obtained in the normal rate condition.

Table III presents the group mean correct scores in per cent for the number of different distinctive features involved, in each time condition, and the "f" score. A Friedman two-way analysis of variance revealed that there were significant differences between correct discrimination and the number of different distinctive features involved. This was true regardless of the time condition. These differences were found to be statistically significant beyond the .001 level of confidence. (Siegel, 1956). The aphasics performed best in all three time conditions when the nonsense syllable pairs were like pairs (e.g. /mis/mis/), with no distinctive

TABLE III

GROUP MEAN PERCENTAGE SCORES FOR THE NUMBER OF DIFFERENT DISTINCTIVE FEATURES INVOLVED, IN EACH CONDITION, AND THE "f" SCORE

# OF DIFFERENT DISTINCTIVE FEATURES	COMPRESSED	NORMAL RATE	EXTENDED	"f" SCORE
1	38	65	25	
2	65	87	46	
3	70	93	54	
4	72	100	67	
5	89	100	72	
0	96	100	90	
				76.85*

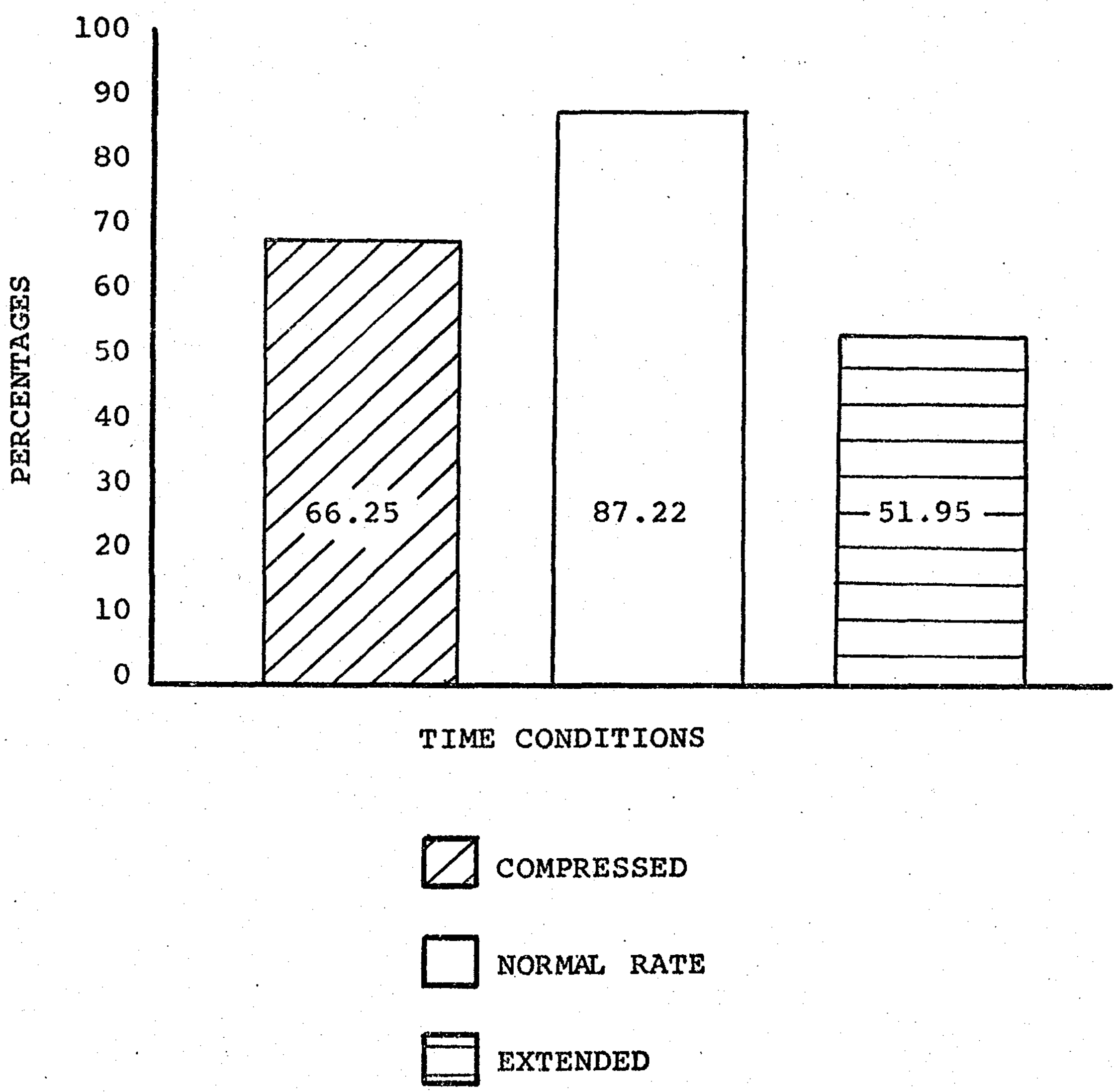
* Significant beyond .001 level of confidence

feature differences. Poorest discrimination scores were recorded, in all three time conditions, when only one distinctive feature difference existed (e.g. /mis/bis/). However, as the number of differing features, seperating the pairs, increased (e.g. /mis/sis/), higher discrimination scores were obtained in all conditions.

Examination in terms of mean percentages of correct discrimination, as illustrated in Figure I, demonstrates

FIGURE I

GROUP MEAN PERCENTAGES OF CORRECT DISCRIMINATION FOR EACH TIME CONDITION



the differences in the aphasics' abilities to discriminate within the three time conditions. The aphasics' group mean discrimination scores were 87.22, 66.25, and 51.95 per cent correct for the normal rate, compressed, and extended conditions respectively. Intrasubject examination, as indicated in Table IV, revealed that each of the subjects demonstrated his poorest discrimination scores in the extended condition. Better discrimination scores were obtained in the compressed condition, and the highest discrimination score for each subject was obtained in the normal rate condition. This is further illustrated in Figure II.

TABLE IV

INTRASUBJECT PERCENTAGE SCORES

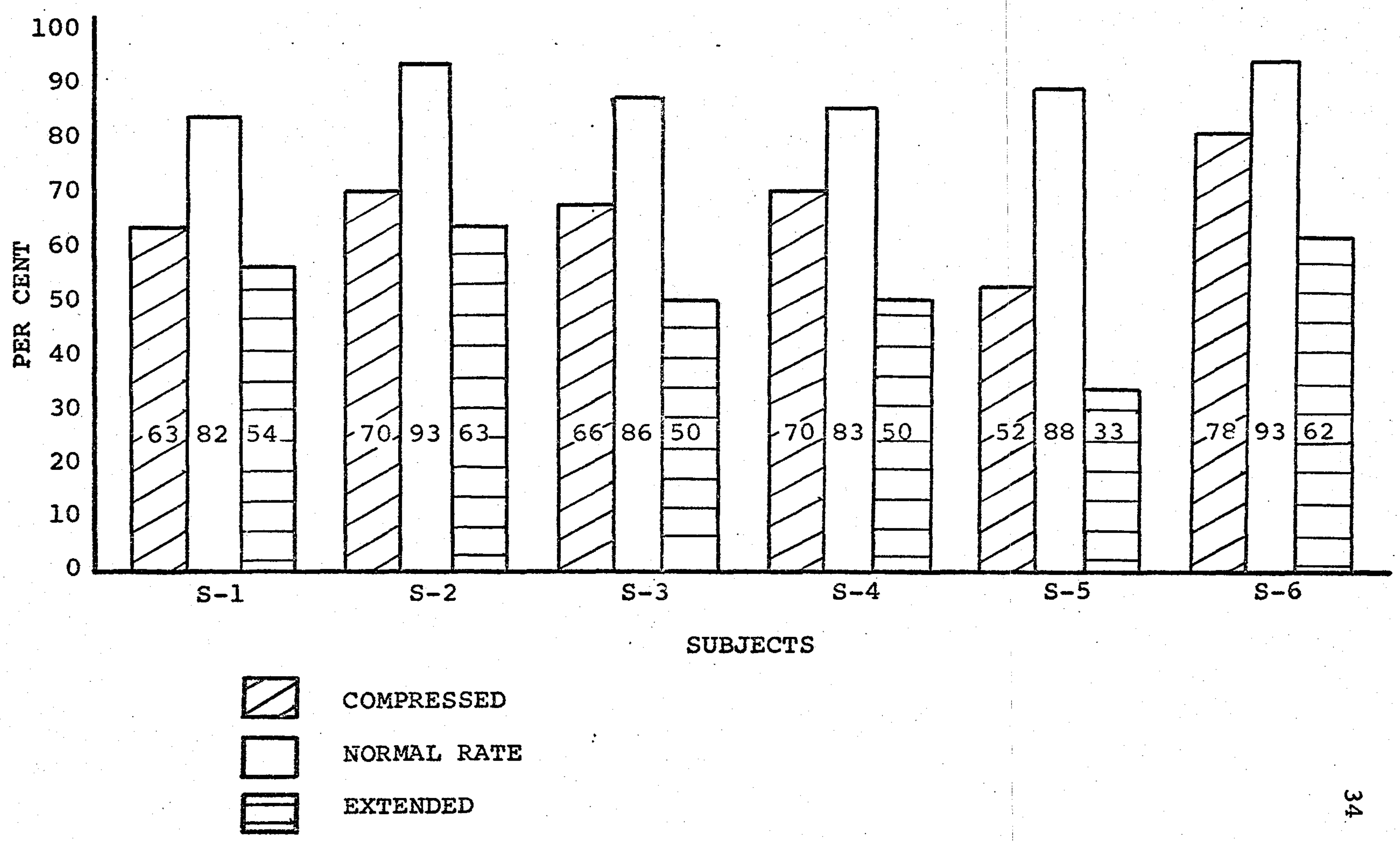
FOR EACH TIME CONDITION

SUBJECTS	COMPRESSED	NORMAL RATE	EXTENDED
S-1	62.5	81.7	54.2
S-2	70.0	92.5	63.3
S-3	65.8	85.8	50.0
S-4	70.0	82.5	50.0
S-5	51.7	88.3	32.5
S-6	77.5	92.5	61.7

FIGURE II

INTRASUBJECT PERCENTAGE SCORES

FOR EACH TIME CONDITION



Additional data of intersubject scores are presented in Table V. This table reveals a wide range of discrimination scores for the six subjects across the three time conditions. In the compressed condition, discrimination scores ranged fram 50.0 to 77.5 per cent. The normal rate condition resulted in discrimination scores that ranged from 81.7 to 92.5 per cent correct; while in the extended condition, correct discrimination scores ranged from 32.5 to 63.3 per cent.

Examination of the group mean percentage scores for the number of different distinctive features involved in each condition is illustrated in Figure III. This figure graphically demonstrates the definite relationship between the number of distinctive feature differences and the number of items correctly discriminated. This relationship was true for all three time conditions.

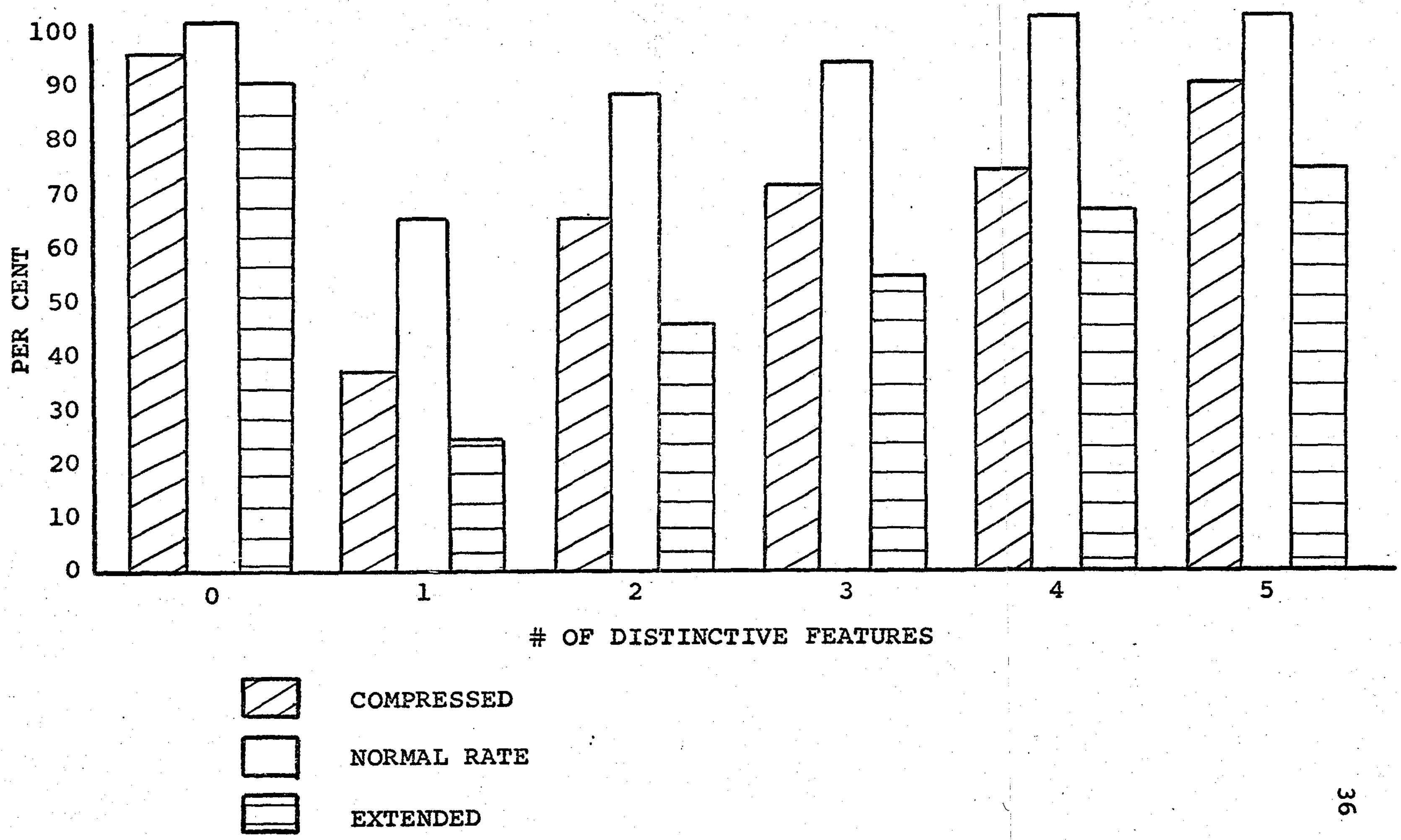
TABLE V

INTERSUBJECT PERCENTAGE RANGE IN TERMS OF CORRECT DISCRIMINATION SCORES ACROSS TIME CONDITIONS

	COMPRESSED	NORMAL RATE	EXTENDED
RANGE	50.0-77.5	81.7-92.5	32.5-63.3

FIGURE III

GROUP MEAN PERCENTAGE SCORES FOR THE NUMBER OF DIFFERENT DISTINCTIVE FEATURES INVOLVED IN EACH CONDITION



Discussion of the Data

Due to the small number of subjects used in the study, statements about the aphasic population's perceptual abilities are difficult to make based on these data. All subjects had received varying amounts of speech and language therapy which may or may not have influenced discrimination scores. Further, many of the subjects had previous experience as participants in auditory perceptual experiments which also may or may not have influenced performance abilities. Finally, the aphasics involved in this study were a very select group, due to the criteria imposed, and are by no means representative of the general aphasic population. Therefore, when the term aphasics is mentioned in this discussion, it refers specifically to those subjects who were involved in the present study.

Analysis of these data indicated that compressed and extended speech do have an effect on the aphasics ability to discriminate nonsense syllable pairs. Although there were statistically significant differences between scores obtained in the three time conditions, the aphasic subjects did not demonstrate a better discrimination score when the rate of the stimulus was extended, as was hypothesized. This finding does not support the contention of Schuell, Jenkins and Jimenez-Pabon (1964), who believed that aphasics would benefit from a message that was spoken a little more slowly than ordinary conversational speech. Their belief, however, was based solely on clinical observations and consequently there were no experimental data to support their contention.

The results of the present study appear to agree in part with the observations of DiCarlo and Taub (1972), who noted that aphasics performed poorest in the experimental conditions in which time-alteration occurred. However, the DiCarlo and Taub, and Parkhurst (1970, 1971) studies noted that compression led to greater errors than expansion. Results of the present study indicate that expansion leads to greater errors than compression. Although all three studies used time-altered speech, there are numerous differences between the studies than may account for the different results.

One major difference between the three studies is that the present study used nonsense syllable pairs in which there was no semantic meaning. The Parkhurst (1971), DiCarlo and Taub (1972) studies used words and sentences in which there was meaning involved and which may or may not have affected comprehension. Although Stoudt (1964) has pointed out that aphasics show no difference in their ability to discriminate between nonsense syllable pairs and word pairs, it may be that there is a difference in the aphasic's ability to discriminate between nonsense syllable pairs and word pairs when they are presented in time-altered conditions.

Other differences between the studies include the amount and the method of time-alteration involved. The DiCarlo and Taub study, like the present one, compressed and extended the stimuli by 50 per cent, whereas, Parkhurst used rates of 32 per cent for compression and 37 per cent for extension. It does not appear that the amount of time-alteration had any influence on the differences between the studies, as both the Parkhurst, and the DiCarlo and Taub studies had similar results using different amounts of compression and expansion. The materials used in the present study were developed by an LM-312 Pitch Normalizer (Harris, 1972), whereas, the material for both the Parkhurst, and the DiCarlo and Taub studies were generated by an Electro Rate Changer (Foulke and Sticht, 1969). Although these are two different instruments, both change the rate of speech while maintaining normal pitch. The difference between the Electro Rate Changer and the Pitch Normalizer is that the Electro Rate Changer is a speech sampler that reproduces periodic samples of a recorded tape. The Pitch Normalizer, on the other hand, is a continuous processing system that reproduces the whole message rather than periodic samples. Therefore, it is conceivable that the methods of time-alteration resulted in the differences between the studies.

Another possible explanation for the difference between the three studies, may be in the tasks employed in the studies. The Parkhurst study, which used a modified form of the Token

Test, was designed to examine the relationship of how rapidly an auditory command could be spoken and how accurately the command could be executed. The DiCarlo and Taub study, was designed to examine how accurately subjects could repeat words they heard at varying rates. In the present study, the subjects were required to discriminate between nonsense syllable pairs presented at varying rates, and to respond nonverbally. Although it is virtually impossible to compare subject results across studies, it is conceivable that the different tasks had an effect on the different findings.

Another possible explanation for the different findings to both the Parkhurst, and the DiCarlo and Taub studies may be found in the comments made by five of the six subjects. The sixth subject made no comments because he was unable to verbally express himself. All five subjects reported that the extended stimuli were the most difficult to listen to, whereas, the normal condition was the easiest. The subjects reported that the extended speech was too drawn out and that it sounded distorted. Furthermore, the subjects complained that there was too much time between the two extended syllable pairs, which often resulted in forgetting the first item presented. Discussing the compressed stimuli, the subjects complained not so much of distortion but rather that the stimuli were presented too rapidly. Analysis of the data support their comments. Apparently, compression and expansion of the stimuli have a perceptually distorting effect upon the material. The data indicates that the distortion effect is sufficient enough to make discrimination for the aphasic even more difficult in the compressed and extended conditions than in the normal presentation rate.

The most reasonable explanation for the poorer performances with expansion, and possibly the cause of the reversed findings to both the Parkhurst, and DiCarlo and Taub studies, was discovered subsequent to the investigation. The investigation took place in March, 1973. In August, 1973, the LM-312 Pitch Normalizer was returned to Lockheed Missiles and Space Company for servicing and it was discovered that three of the filters in the extended mode had been placed in the system backwards. The distortion that was noted in the extended condition, was probably a direct result of the reversed filters. This could explain the poorer performances in the extended condition as well as the different findings.

Luterman, Welsh and Melrose (1966) examined the perception of compressed and extended speech by young and aged normals. Although the stimuli were only time-altered by 10 and 20 per cent, their results revealed that both compression and expansion increased the error rate, however, there was no relationship between age and rate. Sticht and Gray (1969), on the other hand, noted that aged subjects had more difficulty than younger subjects in understanding a time-altered message in both the compressed and extended conditions. Examination of the present study's data in terms of intersubject scores, revealed that no relationship existed between age and discrimination scores regardless of time condition. All subjects, regardless of age, did the poorest in the extended condition and did the best in the normal rate condition. Considering the wide range of ages for the subjects of this study, it is highly unlikely that age had any effect in the findings.

The data further indicated that correct discrimination was positively related to the number of different distinctive features involved. All subjects demonstrated higher discrimination scores when there was a greater number of distinctive feature differences between the nonsense syllable pairs, regardless of time condition.

Another interesting observation is that since correct discrimination was related to the number of feature differences, the question of whether the subjects responded on a chance basis to the discrimination task is virtually eliminated. If the subjects had responded on a chance basis, the correct discrimination scores would not have been related to the number of different distinctive features involved in all three of the time conditions. Furthermore, these findings would tend to indicate that the compressed and extended stimuli had a distorting effect upon the material. Although higher discrimination scores resulted as more information was provided, the compressed and extended stimuli made it more difficult for the subjects to accurately discriminate. Consequently, poorer discrimination scores were achieved in the compressed and extended conditions.

Examination of the data (Appendix F) does not reveal any pattern of learning effect to suggest that more accurate discrimination scores were achieved on the third day as compared to the first day. This was true for all subjects but one.

Scores for the Wepman test, Token test, and Porch Index of Communicative Ability were examined across subjects and were compared to their discrimination scores for the experimental stimuli. There appeared to be no association between performance on the diagnostic tests and discrimination scores on the experimental task.

Although generalizations about aphasics are difficult on the basis of this study, the primary findings indicate that the compressed and extended stimuli did not improve accurate discrimination scores for any of the subjects. Instead, poorer discrimination scores were obtained in the compressed and extended conditions. Furthermore, each subject demonstrated that correct discrimination of nonsense syllable pairs was positively related to the number of different distinctive features involved, regardless of time condition.

CHAPTER V

SUMMARY AND SUGGESTIONS FOR FURTHER RESEARCH

The breakdown in the auditory processing ability of spoken language is frequently observed in the aphasic. However, speech pathologists are still uncertain as to how to deal with this difficulty. Schuell, Jenkins, and Jimenez-Pabon (1964) have suggested that clinical reports often indicate that aphasics have difficulty responding to rapidly presented stimuli. They have noted that people frequently talk too rapidly for the aphasic to understand. These researchers have suggested that one should manipulate the duration of the auditory stimulus so that it becomes easier for the aphasic to perceive the stimulus.

Based on this, the present study was designed to answer the following questions:

(1) what effect does time-altered speech have on the aphasic's ability to discriminate nonsense syllable pairs; and,

(2) is correct discrimination of the syllable pairs positively related to the number of different distinctive features involved, or to the time differences in the time-altered condition.

Method

Six aphasic subjects, ranging in age from 32 to 58 years, with a mean age of 44.2 years, were given the Stoudt (1964) nonsense syllable pair lists in three time conditions (compressed, normal rate, and extended). All subjects were:

(1) native speakers of English;

(2) diagnosed as aphasic by a certified speech pathologist;

(3) left hemisphere lesion aphasics;

(4) able to meet the hearing threshold;

(5) able to respond using the nonverbal response mode employed in this study; and,

(6) able to meet the correct discrimination criterion on the practice material.

Three types of stimulus material (training, practice, and experimental) were presented to all six subjects over a three day period. First, the training material, developed by this experimenter, was presented verbally each day. Then, a list of practice material (Stoudt, 1964) was presented in the normal rate condition, by means of a tape recorder. Finally, the experimental material (Stoudt, 1964), which consisted of three nonsense syllable pair lists, was presented in all three conditions (compressed, normal rate, and extended) also by means of a tape recorder.

The compression and expansion of the experimental material, as well as the normal rate of the practice and experimental material was all done by means of an LM-312 Pitch Normalizer. During the presentation of the stimuli, the subjects indicated their responses by pointing to a nonverbal response mode. Each subjects responses for the practice and experimental material was recorded on a data sheet, by the experimenter. The data were then analyzed statistically and in terms of percentage scores.

Results and Conclusions

A Friedman two-way analysis of variance (Siegel, 1956) revealed the following:

(1) There were statistically significant differences (beyond the .001 level of confidence) between the aphasic's ability to discriminate and the three time conditions. The poorest discrimination scores were obtained in the extended condition. Higher discrimination scores were obtained in the compressed condition, while the highest discrimination scores were obtained in the normal condition.

(2) There were statistically significant differences (beyond the .001 level of confidence) between correct discrimination and the number of different distinctive features involved. Higher discrimination scores were obtained when there was a greater number of different distinctive features between the nonsense syllable pairs, regardless of time

condition.

The data were also subjected to an examination of percentage correct scores. This type of examination revealed that on an intrasubject basis, each of the subjects demonstrated his poorest discrimination scores in the extended condition. Better discrimination scores were obtained in the compressed condition, and the highest discrimination score for each subject was obtained in the normal rate condition.

Due to the small number of subjects used in the present study, statements about perceptual abilities of an aphasic population are difficult to make based on these data.

The results of this investigation showed that the time conditions did affect the aphasic's ability to discriminate the nonsense syllable pairs presented. Discussion with five of the subjects produced complaints that the extended stimuli were too lengthy and that the compressed stimuli were presented too rapidly. It appeared as though the compression and expansion of the stimuli had a distortion effect upon the material. When the LM-312 Pitch Normalizer was returned to Lockheed for servicing, subsequent to this investigation, it was discovered that three of the filters in the extended mode had been placed in the system backwards. The distortion that was noted in the extended condition, was probably a direct result of the reversed filters.

Schuell, Jenkins, and Jimenez-Pabon's (1964) contention that aphasics would respond more adequately if the stimuli were presented a "little more slowly" was not supported by this investigation. The results of this study agreed more with those of Parkhurst (1970, 1971), and DiCarlo and Taub (1972) who all noted, in some degree, that aphasics perform poorest in the experimental conditions with time-altered speech.

The primary findings indicated that the compressed and extended stimuli did not improve accurate discrimination scores for any of the subjects, as was hypothesized. Instead, poorer discrimination scores were obtained in the compressed and extended conditions. Furthermore, each subject demonstrated that correct discrimination of nonsense syllable pairs was positively related to the number of different distinctive features involved, regardless of time condition.

Suggestions for Further Research

The following topics have been suggested for further research by this study.

Of primary importance, the extended stimuli should be reprocessed through the extended mode to determine whether the reversed filters actually did have a distortion effect upon the stimuli.

Further study is also needed to determine if there is a difference in the aphasic's ability to discriminate between nonsense syllable pairs and between word pairs when they are presented in the three time conditions.

A comparative study with normal subjects would be in order to determine whether the poorer discrimination scores in the time conditions were the result of the aphasics brain lesions or due to the time-altering process.

Further study might involve the same stimuli, but with controls for the interstimulus interval during the time-altering process.

Finally, a larger population of aphasic subjects are needed to better estimate whether the findings of this study hold true for the general aphasic population.

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APPENDIXES

APPENDIX A

BIOGRAPHICAL INFORMATION OF SUBJECTS

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6
AGE	46-6	47-8	38-6	58-11	44-5	32-10
MONTHS POST ONSET OF LESION	4	6	18	6	10	45
NATURE OF LESION	LMCAT*	LMCAT*	Traumatic	LMCAT*	LMCAT*	LMCAT*
PRESENCE OF HEMIPARESIS	yes	no	no	slight	slight	yes
AUDIOGRAM 500, 1000, 2000 Hz.	R 20-15-10 L 10-10-15	R 10-5-10 L 0-0-5	R 25-25-25 L 25-10-25	R 5-15-30 L 5-10-20	R 15-15-20 L 10-10-15	R 10-5-0 L 5-0-15
% CORRECT WEPMAN TEST	90.0	90.0	95.0	90.0	92.5	97.5
% CORRECT TOKEN TEST	68.7	64.4	96.9	96.9	98.8	81.6
OVERALL % SCORE ON PICA	25	60	84	82	91	60

* Left Middle Cerebral Artery Thrombosis

APPENDIX B

TRAINING, PRACTICE, AND EXPERIMENTAL MATERIALS

Training Material

1. cat/dog
2. white/white
3. knife/fork
4. desk/hill
5. spoon/spoon
6. coat/shoe
7. left/right
8. dim/dim
9. in/out
10. boy/girl

1. [mik/sik
2. nɛm/ʃɛm
3. rɛl/rɛl
4. gɔb/sɔb
5. reɪb/reɪb
6. bɪs/ʃɪs
7. vɛm/ʃɛm
8. biʃ/biʃ
9. gɪp/θɪp
10. gɔb/pɔb
11. dʌp/dʌp
12. gɪs/vɪs
13. hæs/hæs
14. deɪb/teɪb
15. dɛp/tɛp]

Practice Material

1. [reɪb/leɪb
2. waɪð/laɪð
3. rɛl/rɛl
4. reɪg/dʒeɪg
5. hæs/ræs
6. weɪθ/leɪθ
7. hædʒ/lædʒ
8. leɪθ/reɪθ
9. dʒal/ral
10. weɪtʃ/weɪtʃ
11. laθ/laθ
12. wɔb/hɔb]

Experimental Materials

LIST 1

1. [kɪv/ðɪv
2. gɔθ/gɔθ
3. ʃɪd/zɪd
4. zɪv/dɪv
5. kæv/kæv
6. zuʃ/tuʃ
7. ʃʌp/bʌp
8. tidʒ/pidʒ
9. dib/nib
10. keɪg/peɪg
11. kæz/tæz
12. nidʒ/midʒ
13. kɪp/bɪp
14. bit/zit
15. zʊk/gʊk
16. feɪb/feɪb
17. ðɛt/zɛt
18. ðɛd/pɛd
19. seɪθ/keɪθ
20. gɔdʒ/θɔdʒ
21. fɔp/nɔp
22. zoʊs/noʊs
23. fɛp/tɛp
24. geɪtʃ/feɪtʃ
25. beɪp/meɪp
26. mɪp/fɪp
27. sæf/væf
28. tɔθ/tɔθ
29. feɪb/peɪb
30. goʊm/poʊm
31. θɪb/pɪb
32. zit/kit
33. θɪr/zɪr
34. næf/sæf
35. θit/θit
36. sɪz/θɪz
37. noʊk/ðoʊk
38. pæv/ʃæv
39. θɛp/bɛp
40. ðig/tig]
41. [tʌl/sʌl
42. sæz/sæz
43. ʃeɪt/veɪt
44. næl/tæl
45. maɪf/vaɪf
46. pɪv/dɪv
47. taɪŋ/vaɪŋ
48. doʊʃ/ðoʊʃ
49. ðit/ðit
50. dɛp/vɛp
51. ʃæt/dæt
52. boʊm/zoʊm
53. tɛg/dɛg
54. gæz/mæz
55. voʊk/goʊk
56. kæz/θæz
57. ʃa/na
58. foʊs/ʃoʊs
59. ðæd/væd
60. ʃis/kis
61. kæg/dæg
62. zig/sig
63. paf/zaf
64. boʊf/poʊf
65. θaɪt/θaɪt
66. deɪs/geɪs
67. seɪb/geɪb
68. vɪg/nɪg
69. toʊf/moʊf
70. peɪb/peɪb
71. θɔp/fɔp
72. mʌn/θʌn
73. zuθ/zuθ
74. pɛŋ/sɛŋ
75. mæv/ðæv
76. noʊf/koʊf
77. koʊθ/goʊθ
78. ðɪm/sɪm
79. θʌt/dʌt
80. ðʌt/fʌt]
81. [peɪθ/veɪθ
82. gæk/ðæk
83. ʃam/gam
84. nɔf/θɔf
85. kæb/mæb
86. naɪp/naɪp
87. sɔɪt/fɔɪt
88. veɪt/θeɪt
89. pɛf/mɛf
90. dʌt/sʌt
91. θig/tig
92. ʃuk/suk
93. feɪtʃ/keɪtʃ
94. bɛtʃ/sɛtʃ
95. duŋ/buŋ
96. bɛz/gɛz
97. maŋ/maŋ
98. bɔdʒ/tɔdʒ
99. paθ/naθ
100. bɔv/fɔv
101. fat/zät
102. gal/nal
103. vaʊt/vaʊt
104. mag/nag
105. θʌl/bʌl
106. dis/fis
107. faɪm/vaɪm
108. baɪm/naɪm
109. ʃɛk/ðɛk
110. bʌv/bʌv
111. maθ/daθ
112. meɪg/seɪg
113. ʃeɪg/ʃeɪg
114. gaʊʃ/taʊʃ
115. ʃis/θis
116. tis/ʃis
117. ʃoʊθ/moʊθ
118. væz/kæz
119. voʊm/boʊm
120. dɛs/dɛs]

LIST 2

1. [dɪv/dɪv
2. doʊtʃ/soʊtʃ
3. ʃʊs/kʊs
4. gɔtʃ/pɔtʃ
5. beɪm/veɪm
6. mæf/pæf
7. væs/ɣæs
8. poʊg/foʊg
9. voʊŋ/koʊŋ
10. veɪ/θeɪ
11. fʌl/ʃʌl
12. teɪv/teɪv
13. mis/ʃis
14. faɪdʒ/saɪdʒ
15. naθ/ʃaθ
16. væf/sæf
17. teɪt/ʃeɪt
18. nʌz/nʌz
19. kɪb/θɪb
20. mɪp/fɪp
21. θɪs/ʃɪs
22. mɪʃ/kɪʃ
23. geɪd/veɪd
24. mis/bis
25. gædʒ/tædʒ
26. nʌk/θʌk
27. geɪk/meɪk
28. gɔtʃ/fɔtʃ
29. ʃig/ʃig
30. gʌz/ʃʌz
31. dʌp/tʌp
32. tɛf/fɛf
33. maʊt/saʊt
34. gæk/ɣæk
35. bæv/zæv
36. zɪd/nɪd
37. dɔz/mɔz
38. vaʊʃ/paʊʃ
39. dʌp/ʃʌp
40. nip/fip]
41. [biʃ/biʃ
42. ɣæs/fæs
43. dɪs/vɪs
44. gɔs/θɔs
45. ɣɛk/ʃɛk
46. dib/θib
47. ɣæz/ɣæz
48. kif/sif
49. bʌθ/nʌθ
50. ɣɪm/sɪm
51. dɛp/ɣɛp
52. ɣiŋ/piŋ
53. veɪb/feɪb
54. gʊv/kʊv
55. vɪtʃ/tɪtʃ
56. zɛt/ɣɛt
57. daɪp/faɪp
58. næθ/kæθ
59. pɪf/dɪf
60. fɔs/fɔs
61. bʌʃ/θʌʃ
62. ɣʌdʒ/mʌdʒ
63. vaɪd/maɪd
64. gud/zud
65. mɛŋ/nɛŋ
66. pædʒ/sædʒ
67. neɪs/teɪs
68. vin/zin
69. veɪt/veɪt
70. zɪθ/zɪθ
71. vaɪt/ʃaɪt
72. bɪv/kɪv
73. gɪm/nɪm
74. mæŋ/θæŋ
75. seɪg/seɪg
76. ziʃ/miʃ
77. zɪm/fɪm
78. fik/θik
79. sʌt/tʌt
80. tɔɪg/kɔɪg]
81. [bʊv/fʊv
82. peɪb/peɪb
83. ɣæl/tæl
84. keɪθ/peɪθ
85. nɔɪd/pɔɪd
86. mɛb/tɛb
87. bʌp/ɣʌp
88. neɪk/deɪk
89. bæz/tæz
90. væd/næd
91. pʊθ/ʃʊθ
92. tuv/puv
93. meɪʃ/meɪʃ
94. geɪg/deɪg
95. ɣoʊb/noʊb
96. bul/ʃul
97. bæv/gæv
98. deɪʃ/geɪʃ
99. sɪf/θɪf
100. zal/tal
101. bɪv/dɪv
102. ɣaɪk/θaɪk
103. θɔs/θɔs
104. kɔθ/kɔθ
105. beɪp/seɪp
106. bɔtʃ/pɔtʃ
107. nɪm/sɪm
108. zuŋ/duŋ
109. kum/fum
110. zav/pav
111. zɪr/θɪr
112. zoʊk/ʃoʊk
113. ʃɛm/sɛm
114. zoʊm/soʊm
115. zɪb/kɪb
116. gʌz/gʌz
117. tɪʃ/θɪʃ
118. doʊf/koʊf
119. pig/θig
120. ɣɛt/kɛt]

LIST 3

1. [daɪt/daɪt
2. veɪp/beɪp
3. keɪŋ/veɪŋ
4. ʃeɪb/meɪb
5. ʃal/tal
6. ʃib/θib
7. tɔθ/gɔθ
8. ʃaz/ʃaz
9. saɪd/maɪd
10. maɪf/daɪf
11. biθ/biθ
12. ʃɛk/ðɛk
13. niʃ/biʃ
14. fæs/væs
15. fɪdʒ/dɪdʒ
16. θʌp/bʌp
17. nug/mug
18. voʊm/voʊm
19. nal/gal
20. foʊv/zoʊv
21. fæz/bæz
22. pim/nim
23. tʊv/bʊv
24. mɪv/mɪv
25. gʌv/bʌv
26. dʌp/bʌp
27. sɔʃ/bɔʃ
28. faθ/kaθ
29. sɔp/ʃɔp
30. θɪs/tɪs
31. sitʃ/ditʃ
32. pæf/mæf
33. θeɪd/veɪd
34. sib/fib
35. nav/nav
36. kaɪd/maɪd
37. θɪg/nɪg
38. ʃeɪb/geɪb
39. ðæk/gæk
40. paɪŋ/vaɪŋ]
41. [fɛb/ðɛb
42. θʌp/dʌp
43. sig/ðig
44. keɪθ/geɪθ
45. kʌz/nʌz
46. mɪp/ðɪp
47. sif/pif
48. zoʊb/zoʊb
49. θʌŋ/mʌŋ
50. θɪm/fɪm
51. pab/pab
52. tʌθ/mʌθ
53. naɪr/vaɪr
54. sɪtʃ/gɪtʃ
55. gʌdʒ/dʌdʒ
56. θaɪk/ðaɪk
57. pæv/bæv
58. pab/zab
59. sɪm/zɪm
60. kas/das
61. keɪf/ʃeɪf
62. ðæm/væm
63. ʃig/fig
64. ʃʊŋ/nʊŋ
65. θɔʃ/kɔʃ
66. vaɪk/gaɪk
67. mæv/gæv
68. tʌp/dʌp
69. zɪk/bɪk
70. ʃaʊ/daʊ
71. vaɪb/daɪb
72. ðoʊt/ðoʊt
73. ðæk/dæk
74. toʊb/voʊb
75. dɪv/pɪv
76. mɛk/vɛk
77. tɪd/nɪd
78. ʃɪd/vɪd
79. seɪb/seɪb
80. teɪb/seɪb]
81. [tɛg/ðɛg
82. ðæf/bæf
83. ʃɔv/pɔv
84. noʊk/ðoʊk
85. θɔm/sɔm
86. θʌb/θʌb
87. seɪg/neɪg
88. θɪm/zɪm
89. kɪr/zɪr
90. θæf/pæf
91. pif/gif
92. faɪm/paɪm
93. tɔb/tɔb
94. sæf/væf
95. feɪtʃ/meɪtʃ
96. bis/mis
97. fɪk/gɪk
98. fɪdʒ/tɪdʒ
99. næθ/zæθ
100. feɪtʃ/neɪtʃ
101. θʌf/gʌf
102. sʌg/kʌg
103. poʊt/ðoʊt
104. ðɛt/zɛt
105. foʊp/foʊp
106. zuk/guk
107. zig/vig
108. kad /bad
109. miθ/ziθ
110. kæz/tæz
111. pɔv/kɔv
112. dɛg/nɛg
113. pɪv/tɪv
114. ʃɛm/bɛm
115. toʊs/zoʊs
116. kɔɪð/kɔɪð
117. dug/zug
118. ʃæn/zæn
119. gaɪf/gaɪf
120. kʌŋ/ðʌŋ]

Errata

The lists of the auditory discrimination task are presented in this appendix as they were administered to the subjects.

Errors were discovered in these lists after the testing was completed. The following corrections are presented so that each list might conform to the distribution of sound contrasts which were basic to Stoudt's (1964) construction of these lists.

List	Item	Given	Should Be
1	12	[nidʒ/midʒ]	[zidʒ/midʒ]
	14	[bit/zit]	[vit/zit]
	39	[θεp/bεp]	[ðεp/bεp]
	65	[θaɪt/θaɪt]	[θaɪt/ðaɪt]
2	14	[faɪdʒ/saɪdʒ]	[faɪg/saɪg]

APPENDIX C

SPECIFIC SOUND CONTRASTS ARRANGED ACCORDING TO NUMBER AND COMBINATIONS OF MILLER AND NICELY PERCEPTUAL CHARACTERISTICS

0 MILLER AND NICELY PERCEPTUAL CHARACTERISTICS

b/b	d/d	f/f
g/g	k/k	m/m
n/n	p/p	s/s
t/t	v/v	z/z
θ/θ	ʃ/ʃ	ð/ð

1 MILLER AND NICELY PERCEPTUAL CHARACTERISTIC

Voicing	Affrication	Duration	Nasality	Place
b/p	p/f	s/θ	m/b	t/p
d/t	b/v	z/ð	n/d	t/k
g/k	t/θ			k/p
v/f	d/ð			b/d
z/s				b/g
ð/θ				d/g
				m/n
				f/θ
				s/ʃ
				v/ð

2 MILLER AND NICELY PERCEPTUAL CHARACTERISTICS

Voice-Nasality	Nasality-Affrication	Voice-Duration
m/p	v/m	z/θ
n/t	n/ð	s/ð

Duration-Place	Voice-Affrication	Nasality-Place
f/s	b/f	b/n
v/z	v/p	d/m
f/ʃ	d/θ	g/m
θ/ʃ	t/ð	g/n

Affrication-Place		Affrication-Duration	Voice-Place	
k/f	p/θ	s/t	b/t	g/t
g/v	k/θ	z/d	b/k	v/θ
t/f	g/ð	k/ʃ	d/p	f/ð
d/v	b/ð		d/k	z/ʃ
			g/p	

3 MILLER AND NICELY PERCEPTUAL CHARACTERISTICS

Nasality-Affrication-Duration
z/n

Nasality-Affrication-Place
v/n
m/ð

Voice-Nasality-Affrication
m/f
n/θ

Voice-Affrication-Duration
d/s
z/t
g/ʃ

Voice-Duration-Place
z/f
s/v
v/ʃ
ð/ʃ

Voice-Nasality-Place
m/t
m/k
n/p
n/k

Voice-Affrication-Place
g/f
v/k
d/f
v/t
b/θ
g/θ
p/ð
k/ð

Affrication-Place-Duration
p/s
k/s
b/z
g/z
p/ʃ
t/ʃ

4 MILLER AND NICELY PERCEPTUAL CHARACTERISTICS

Nasality-Affrication-Place-Duration
z/m

Nasality-Affrication-Voice-Duration
n/s

Nasality-Affrication-Voice-Place
n/f
m/θ

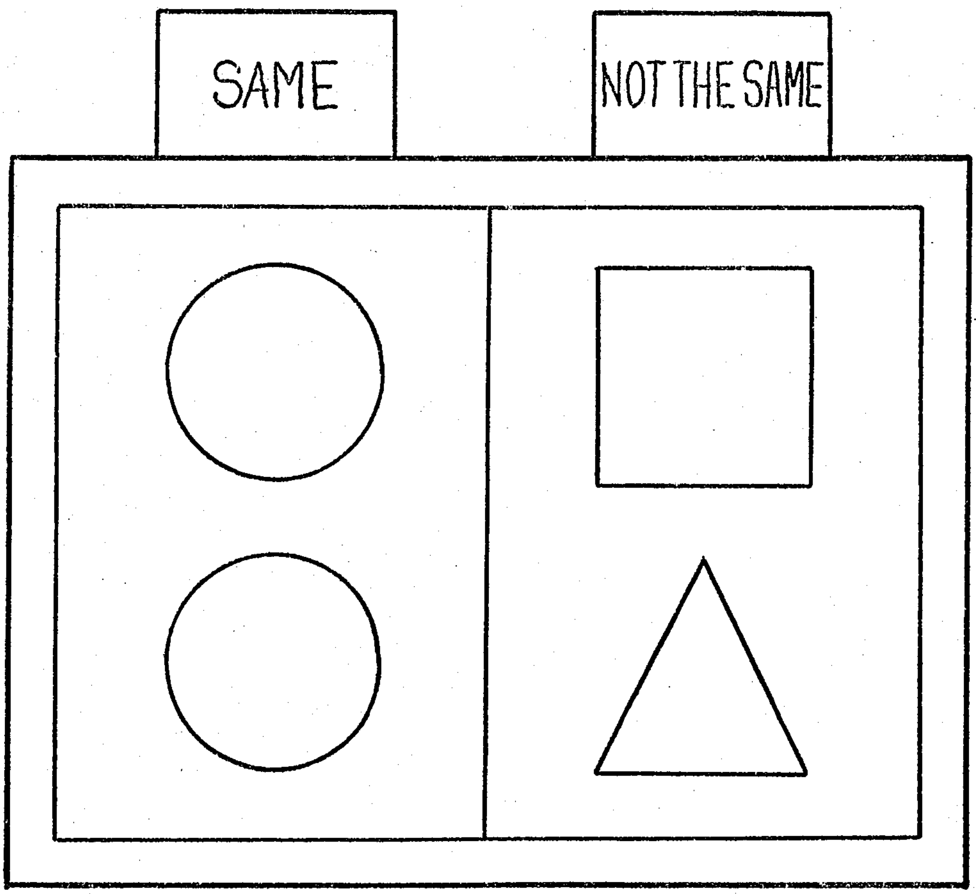
Affrication-Duration-Voice-Place
z/k
z/p
g/s
b/s
b/ʃ
d/ʃ

5 MILLER AND NICELY PERCEPTUAL CHARACTERISTICS

Voice-Nasality-Affrication-Place-Duration
m/s
m/ʃ
n/ʃ

APPENDIX D

NONVERBAL RESPONSE MODE



APPENDIX E

COUNTER BALANCED DESIGN USED FOR STIMULI PRESENTATION

	SUBJECT	DAY 1	DAY 2	DAY 3
CONDITIONS LISTS	1	CNE 123	NEC 231	ECN 312
CONDITIONS LISTS	2	NEC 123	ECN 231	CNE 312
CONDITIONS LISTS	3	ECN 123	CNE 231	NEC 312
CONDITIONS LISTS	4	CEN 123	NCE 312	ENC 231
CONDITIONS LISTS	5	NCE 123	ENC 312	CEN 231
CONDITIONS LISTS	6	ENC 123	CEN 312	NCE 231

APPENDIX F

INDIVIDUAL SUBJECT RAW SCORES IN PER CENT CORRECT

SUBJECT	PRACTICE-DAY 1	PRACTICE-DAY 2	PRACTICE-DAY 3	PRACTICE MEAN	COMPRESSED-DAY 1	COMPRESSED-DAY 2	COMPRESSED-DAY 3	COMPRESSED MEAN	NORMAL RATE-DAY 1	NORMAL RATE-DAY 2	NORMAL RATE-DAY 3	NORMAL RATE MEAN	EXTENDED-DAY 1	EXTENDED-DAY 2	EXTENDED-DAY 3	EXTENDED MEAN
S-1	75.0	75.0	75.0	75.0	40.0	70.0	77.5	62.5	72.5	80.0	92.5	81.7	50.0	55.0	57.5	54.2
S-2	91.6	100	91.6	94.4	67.5	72.5	70.0	70.0	97.5	92.5	87.5	92.5	62.5	62.5	65.0	63.3
S-3	75.0	91.6	91.6	86.1	60.0	70.0	67.5	65.8	77.5	82.5	97.5	85.8	37.5	60.0	52.5	50.0
S-4	66.6	75.0	66.6	69.4	55.0	85.0	70.0	70.0	87.5	82.5	77.5	82.5	52.5	52.5	45.0	50.0
S-5	83.3	75.0	91.6	83.3	37.5	45.0	72.5	51.7	92.5	87.5	85.0	88.3	37.5	20.0	40.0	32.5
S-6	91.6	91.6	91.6	91.6	82.5	72.5	77.5	77.5	95.0	92.5	90.0	92.5	57.5	62.5	65.0	61.7