PERCEPTION OF TIME-COMPRESSED ENGLISH CNC MONOSYLLABLES BY NON-NATIVE SPEAKERS

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ABSTRACT

PERCEPTION OF TIME-COMPRESSED ENGLISH CNC MONOSYLLABLES BY NON-NATIVE SPEAKERS

by

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Speech discrimination tests have in general been found unsatisfactory in the evaluation of central auditory disorders. One of the ways of increasing the efficiency of discrimination tests is through modifying the temporal characteristics of the speech stimuli through time compression. Prior to employing time-compressed speech stimuli in evaluating pathological conditions, normative data must be obtained. Whereas such data are available for native speakers of English, variability in the performance of non-native speakers has not been investigated. This is an important issue because cross-language studies have indicated that subjects experience difficulties in discrimination of speech stimuli which are not contrastive in their native language.

The purpose of the present study was to examine the effects of time compression on the intelligibility of English CNC monosyllabic words, specifically, the N.U. Auditory Test No. 6, among native speakers of Spanish and Indo-Dravidian languages who were proficient in English. Proficiency in English was defined as a minimum score of 80 on the Michigan Test of Aural Comprehension and a score 85 on the Michigan Test for English Language Proficiency.

Seventy two subjects from each of the two language groups, Spanish and Indo-Dravidian, were randomly assigned to six time-compression conditions--0, 30, 40, 50, 60, and 70%. The assignment was such that there were 12 subjects from each language group under each of the six time-compression conditions. Each subject was presented with four lists of monosyllabic words at five sensation levels--8, 16, 24, 32 and 40 dB (re: SRT). For each subject the list presented at the lowest (8 dB) and the highest (40 dB) sensation level were identical. The word lists and the sensation levels were randomized. In addition, the test stimuli were presented unilaterally to each subject such that there was equal representation of right and left ears within each time-compression condition.

The results revealed that with increasing time compression, there was deterioration in the mean discrimination scores for both language groups, the Indo-Dravidian group being more adversely affected than the Spanish group. The interaction effect between time compression and language was statistically significant. With increasing sensation levels, the adverse effect of time compression was offset to a certain extent. A significant interaction effect between time compression and sensation levels indicated that the improvement with increasing sensation levels was not uniform under all time-compression conditions. Further, the interaction between sensation level and language implied that the effect of sensation level was not equal in both language groups. Comparison of the mean discrimination scores from native and non-native speakers revealed that the native speakers scored higher at all compression levels employed. Further, the slope of the articulation function was steeper for the native speakers than for either of the two groups of non-native speakers.

The following conclusions seem warranted. Non-native speakers of English show significant differences in the perception of time-compressed English CNC monosyllables. Of the two groups, Spanish speakers performed significantly better than the Indo-Dravidian speakers. In comparing native with non-native speakers, it was found that native speakers performed better than non-native speakers in the perception of time-compressed English CNC monosyllables.

Increasing levels of time compression has a detrimental effect on the perception of monosyllabic words. There is variability in the extent to which two groups of non-native speakers are adversely affected. With increasing compression levels, there was a greater breakdown in the response of the Indo-Dravidian speakers than the Spanish speakers.

With increasing sensation levels, the adverse effect of time compression is offset to a certain extent. The magnitude of the gain varies as a function of the native language of the listeners. Whereas the native speakers of English derived the maximum benefit, the Indo-Dravidian speakers derived the least benefit from increasing sensation levels.

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CHAPTER ONE

INTRODUCTION

Perception is one of the most fundamental aspects of human cognition. As such, it must be very simple and immediate, but psychologically, perception is exceedingly complex. It is an integral part of ordering and evaluating stimuli in planning a response.

To arrive at a perceptual configuration, previous experience with the stimuli to be perceived is as crucial as the features of the sensory impressions that might have suggested it. With the sensory input, past experiences associated with similar stimuli are evoked. These memory images, together with the immediate sensory impressions act as the determinants of the response. Thus, based on a perceiver's past experience, each perceptual event becomes unique to each individual.

Under normal conditions, factors such as motivation and anticipatory set from the perceiver himself, or some prominent feature of the perceived object may dominate the perceptual process. Anticipatory set implies a readiness to name the percept, or to fit it into a preconceived category. If the perceived stimulus is not what was anticipated, the tendency is to find an analogous category or name.

Anticipatory set may enhance perceptual accuracy, but it may also lead to errors. The set may be inappropriate, or in trying to fit the percept into a preset category, some parts of the sensory impressions may not be taken into account. So, we may have false perceptions which are more consistent with the anticipatory set rather than the impinging stimuli.

Not all perceptual errors are caused by the anticipatory set. False perceptions may also be caused by pathological conditions present in the organism. In such instances, perceptual errors may be due to faulty reception by the sense organ, imperfect transmission along the sensory pathway or poor integration by the central nervous system.

Perceptual errors are not without value. By studying instances where perception is in error, we may know how correct perception is brought about. Through perceptual errors, it is possible to discover the pathological conditions present in the organism. Clinical audiology is one of the several disciplines that utilizes perceptual errors for diagnostic purposes.

Perceptual Errors and Clinical Audiology

In clincial audiology, the state of the auditory system is evaluated by means of the deviant responses to a set of known stimuli. Standard clinical audiometry utilizes both pure-tone and speech stimuli. Audiometric tests employing speech stimuli are routinely used to obtain two measures, the speech reception threshold and the speech discrimination score. The former is defined as the intensity level at which the listener is able to repeat 50% of the stimuli presented to him. The latter, speech discrimination score, is obtained at supra-threshold levels, by employing monosyllabic word lists that have been specifically developed for this purpose (Egan, 1948; Hirsh et al., 1952;

Lehiste and Peterson, 1959; Peterson and Lehiste, 1962; Tillman, Carhart and Wilbur, 1963; Tillman and Carhart, 1966).

Through discrimination testing, it is possible to obtain some estimate of the extent of the sensorineural involvement; the poorer the discrimination score, the greater is the involvement of the sensorineural mechanism (Carhart, 1965). As part of a test battery, discrimination scores aid in differential diagnosis of cochlear and retrocochlear lesions. Further, disproportionate loss of discrimination is indicative of a phenomenon referred to as 'phonemic regression (Gaeth, 1948).

Although discrimination tests have served their purpose well in the diagnosis of peripheral hearing loss, they have not been as efficient in detecting lesions in the central auditory system. Neither reduced hearing sensitivity nor poor auditory discrimination is an inevitable consequence of lesions above the brainstem (Katz, 1962; Willeford, 1969; Hodgson, 1972). Because there is redundancy within both the central auditory system and the speech signal, the presence of cortical lesions is difficult to detect at the behavioral level. This statement is elaborated below. Each ear has representations in the projection areas of both cerebral hemispheres. So, unilateral lesions are difficult to uncover due to the compensations extended by the opposite hemisphere (Luria, 1973). The redundancy in the speech signal is such that, as Miller and Licklider (1950) demonstrated, intelligibility is not imparied even though part of the signal may not be available to the perceiver.

For clinical purposes, the redundancy within the auditory system cannot be deducted. However, attempts have been made to increase the efficiency of the speech signal through filtering (Bocca, 1955; Bocca et al., 1955; Calearo, 1957; Jerger, 1964), acceleration of speech (Bocca and Calearo, 1963), masking with noise (Jerger, 1964) and through superimposition of competing messages (Katz, 1962; Jerger, 1964).

Temporal Integration and Audition

Of the several procedures available for increasing the discriminative efficiency of the speech signal, those manipulating the temporal characteristics, such as accelerated speech would seem to be more promising in identifying lesions in the central auditory system, for several reasons. First, audition is a time-based sense modality (Hirsh, 1952). Whereas in vision, the spatial aspect of the sensation predominates, in audition it is the temporal aspect such as rhythm, temporal sequence and duration that predominates (Holůbar, 1969). Davis (1956) noted, "Time, either in the direct sense of now, of duration or of rhythm or in the less direct sense of frequency of occurrence is a primary aspect of audition" (p. 189).

Second, it has been suggested that temporal integration reflects integration of the highest degree, implying participation of the central nervous system. A lesion in the central nervous system may, therefore, be expected to correlate with poor temporal integration. Studies with human and laboratory animals support this hypothesis. It has been reported that aphasic subjects required much longer interstimulus intervals to report accurately the order in which the stimuli, both visual and auditory, were presented (Efron, 1963). Similarly, with bilateral temporal lobe lesions, difficulty in perceiving the stimuli in sequence was evident in the auditory modality (Jerger et al., 1969). Other difficulties due to cortical lesions are, elevated thresholds in the perceptions of short duration sounds and in discrimination between rhythms (Luria, 1973). In animal studies, the results show that following cortical ablations, cats could be trained on tasks demanding intensity and frequency discriminations, but their performance was poor on tasks demanding discrimination between combinations of acoustic stimuli (Neff, 1964; Masterton and Diamond, 1964).

Accurate perception of temporal sequence is necessary to discriminate between words like /æks/ and /æsk/ (Hirsh, 1959). From the studies reported earlier on subjects with cortical lesions, it may be anticipated that a lesion in the central auditory system would be reflected in poor discrimination of the sound sequences. Thus it appears that a task requiring accurate sequential perception, but limited in its temporal characteristics would be most suitable in assessing central auditory disorders. This criterion could be satisfied through accelerating the speech signal.

In accelerating speech, the amount of time required for transmitting a message is reduced. Speech thus altered is sometimes referred to as time-compressed speech (Foulke and Sticht, 1969).

Techniques for Acceleration of Speech Signal

The simplest and the most obvious technique would be to have the speaker increase the rate of his speech. This procedure has been adopted by some investigators (Calearo and Lazzaroni, 1957; deQuiros, 1964). The chief merit of this technique is that the experimentor does not have to resort to special equipment. In experimental studies and clinical application, however, this technique has limited utility due to inter- and intra-speaker variability and due to the limits placed on the rates of acceleration that can be achieved.

The speech signal may also be accelerated by reproducing the recorded signal at rates higher than those at which they were recorded. Such a procedure would not only increase the rate, but would also change the pitch characteristics of the reproduced signal, making it a less desirable procedure than it would otherwise be.

An improvement over the above two procedures is the sampling procedure which selectively deletes portions of a signal. This procedure was originally employed by Miller and Licklider (1950). A modification in the sampling procedure introduced by Garvey (1953) amounted to abutting the signal after it had been interrupted periodically. This procedure yielded time-compressed, intelligible speech without introducing distortions related to increased pitch. A drawback of this procedure is that it is laborious and time consuming, requiring manual cutting and splicing of the recorded tapes. These disadvantages may be overcome by employing the electromechanical apparatus described by Fairbanks, Everett and Jaeger (1954). By means of this apparatus, which reproduces periodic samples of recorded speech, time-compressed speech without alterations in pitch may be obtained. Other methods of achieving time-compression are by means of computers and the technique of speech synthesis.

Linguistic Experience and Speech Perception

With the availability of improved techniques of time compression, sources of error in the diagnosis of auditory disorders may be minimized. However, in a given case, the errors in diagnosis may be augmented by the listener himself. As Miller (1951) noted, "The perceiver contributes a selective function by responding to some aspects of the total situation and not to others. ... And he supplements the inconsistent or absent stimulation in a manner that is consistent with his needs and his past experience" (p. 79). Among the listener's past experience, his linguistic experience is especially important in optimum speech perception (Lehiste and Peterson, 1959; Hirsh, 1965; Lloyd and Young, 1969).

An aspect of linguistic experience that has received considerable attention from the psychologists, educators and linguists is bilingualism, or the ability to use two languages alternately. In becoming a bilingual, an individual acquires competency in two linguistic systems. Each system involves units constructed and organized differently from the other and involves diverging grammatical rules and lexical items. Ideally, the two systems would remain distinct, but in reality, where two languages coexist, one system is known to influence the other (Gumperz, 1964). In speech production, the influence may be at the phonological, the lexical or at the grammatical levels (Weinreich,1970). Cross-level influence has also been observed (Bickerton, 1971).

At the perceptual level, the segments of the second language may filter through those of the native language such that they are underdifferentiated (Haugen, 1957; Weinreich, 1970. Or the discrimination that is habitual in the native language may be extended to the second language, resulting in overdifferentiation (Weinreich, 1963; Boas 1967). For example, the Indian speakers of English may fail to discriminate between /v/ and /w/ in English because such a differentiation is not meaningful in their native languages. Conversely, the Indian speakers who discriminate between the aspirated and the unaspirated stops, have been known to extend this habit to English in which such a discrimination is not necessary (Pandit, 1964).

Literature on bilingualism pertaining to auditory perception has included comparison of monolingual and bilingual subjects in their ability to discriminate between phonological sequences (Rabinovitch and Parver, 1966; Davine, Tucker and Lambert, 1971; Politzer and McMahon, 1970) between syllables (Singh, 1966) and lexical items (Black and Tolhurst, 1955; Black and Hast, 1962; Goto, 1971). Also reported are, comparison between auditory and visual comprehension (Tireman and Woods, 1939), discrimination between the acoustic cues in the speech and the nonspeech mode (Miyawaki et al., 1973) and comparison between temporally altered speech and normal speech (Johnson and Friedman, 1971). From the point of view of audiological evaluation, there is virtually no information available concerning the use of time-compressed speech with bilingual subjects.

Need for the Study

As mentioned earlier, in clincial audiometry, the basis for diagnosis of auditory pathology is the deviant response made to a set of known stimuli. Prior to explorations of the pathological conditions, a prerequisite to be met is the establishment of norms on normal subjects. In other words, in order to categorize a response as deviant, we must know from what it deviates. Such a prerequisite has been met for the native speakers of English (Beasley, Schwimmer and Rintelmann, 1972; Beasley, Forman and Rintelmann, 1972).

For purposes of comparison between the normal and the abnormal, it appears that caution must be exercised in using the normative data obtained from the native speakers with the non-native speakers, for several reasons. First, variability in the perception of identical stimuli have been attributed to differences in the native languages of the listeners. By employing synthetic speech stimuli, Delattre (1964) discovered that the stimulus perceived as /s/ by American speakers was perceived as /ʃ/ by the French. Further, the point at which there was a perceptual change from /s/ to /ʃ/ was not identical to the two groups.

Second, with natural speech as stimuli, it has been demonstrated that the native speakers not only develop the competency in producing a set of speech sounds, but also a differential sensitivity in perceiving these sounds (Politzer and McMahon, 1970; Goto, 1971). Due to such a differential sensitivity, an apparent discrimination loss may be induced when the test stimuli are in the non-native language of the listener. The apparent discrimination loss in these subjects may be equated with a true discrimination loss, resulting in erroneous diagnosis.

Third, several investigators have reported variability in the performance of the native and the non-native speakers of English on audiological tests such as the delayed auditory feedback (Rouse and Tucker, 1966; Hanley, 1968). This lends further support to the argument that audiological tests and procedures cannot be used for a population whose linguistic characteristics are not comparable to the population on which they were standardized.

Establishing the appropriateness of time-compressed discrimination tests in English for the non-native speakers is justified because the incidence of bilingualism seems to be increasing. In many developing nations, languages which were used to a limited extent until recently, are being revived for a wider usage. But, English continues to be used for technological and scientific purposes. So of necessity, an increasing number of people in these countries are becoming bilingual. In addition, personal gain through travel and education may also incite people to become bilinguals.

Further justification for validation of the current discrimination tests on bilingual population accrues from the fact that in many multilingual countries such as India, discrimination tests in the indigenous languages are presently not available. Validation of the tests in English may be valuable for interim usage.

Although not generally considered a multilingual country, the U.S. has a large bilingual population with the Mexican-Americans in the southwest, the Puerto Ricans in the east and the native Indians scattered in various parts of the country. Further, the Bilingual American Education Act, passed as Title VII of the Elementary and Secondary Education Act of 1965, provides facilities for the bilingual citizens to receive education through their native language as well as through English.

In doing so, it promises, potentially, a growing bilingual population in addition to the immigrants and the residents. So, it appears that a need exists in ensuring the compatibility between the discrimination tests and those who may need diagnostic evaluations through these tests.

Definition of Terms and Description of Test Materials

For the purpose of this study, bilingualism is defined as the proficiency in two or more languages, i.e., in the native and the target (second) languages. The native language is identified as the language, other than English, that is acquired from the parents. For this study, Spanish and the Indo-Dravidian languages will be identified as the native languages and English, as the target or second language. The target language may be acquired after or simultaneously with the native language.

Proficiency in English is defined as a minimum score of 80 on the Test of Aural Comprehension and a minimum score of 85 on the English Language Proficiency Test. These scores signify that a student who is not a native speaker of English, is able to carry a full academic load at a university in the U.S.

The Michigan Test for Aural Comprehension purports to measure the comprehension of spoken English by non-native speakers. It consists of sixty sentences or short paragraphs. On hearing the stimuli, the student selects the appropriate alternative from a group of three pictures or phrases. The reliability was reported between 0.87 and 0.88 (Lado, 1957).

The Michigan Test for English Language Proficiency was designed to predict readiness for the academic success of non-native speakers. It is a multiple-choice test of grammar, vocabulary and reading comprehension. The norms were established on college students of varying academic levels and fields of specialization. For the present study, the reading comprehension subtest was not utilized.

The test stimuli for the present study consisted of CNC monosyllabic words, specifically the N.U. Auditory Test No. 6 (Tillman and Carhart, 1966). It consists of four lists randomized in four forms. Each list consists of 50 monosyllabic words. The development of these word lists was based on an earlier version, the N.U. Auditory Test No. 4 (Tillman, Carhart and Wilbur, 1963), which consists of two lists phonemically balanced to meet the criteria proposed by Lehiste and Peterson (1959). A revision of the N.U. Auditory Test No. 4 was necessitated to meet the demands for more alternative forms of the test for experimental and clincial purposes. The revised list, N.U. Auditory Test No. 6, provided two additional lists, each with four forms--A, B, C and D. For the present study, Form B was utilized.

The languages of the world, estimated to be between 2800 and 3000, are classified into 13 major categories (Muller, 1964). The languages within a major category are believed to be more similar to each other with respect to syntax and lexicon, and to a lesser extent phonology, than to those languages outside a given category. Of the language groups employed in the present study, Spanish and the languages within the Indic group are members of the Indo-European languages. The Indic and the Dravidian languages are the two main categories to which the languages of India belong.

Besides being spoken by millions of people in various parts of the world, Spanish is the native language of many people in the south-western parts of the United States, California and Florida. It is not only the official language in Spain and in 18 Latin American Republics, but is also recognized as co-official with English in the State of New Mexico in the United States.

The Indic languages are spoken by approximately 350 million people in south Asia. They are also prevalent in Southern Africa, the South Pacific, the Antilles, the Guianas of South America, Afghanistan and on the Andaman and Nicobar Islands (Voegelin and Voegelin, 1965). Some prominent Indic languages are: Hindi, Marathi, Bengali, Assamese, Gujerati, Punjabi, Oriya and Bihari.

The Dravidian languages are concentrated in India, specifically in the southern and the south-eastern parts of the country. They are also spoken in Pakistan and Ceylon. Prominent among the Dravidian languages are: Tamil, Telugu, Kannada and Malayalam.

Although linguists generally do not classify the Indic and the Dravidian languages under the same major category, these two language groups are combined in the present study. It appears reasonable to do so because, due to mutual influences there are similarities in phonology between these language groups (Andronove, 1964). The mutual influence, to a large extent is due to the widespread bilingualism prevalent as a consequence of the arrival of the Indic languages on the Indian subcontinet in the second milleniun B.C. Since this historic occurrence, geographical proximity has further facilitated an interaction between these two language groups, resulting in an increase in the similarities between the Indic and Dravidian languages and a decrease in the elements relating the Indic languages to the other Indo-European languages (Andronove, 1964).

Summary and Statement of the Problem

Speech discrimination tests have been found unsatisfactory in evaluating central auditory disorders. The rationale for increasing the efficiency of the discrimination tests through modification of the temporal characteristics, such as time compression were discussed. Prior to utilizing the time-compressed stimuli with an abnormal population, normative data on the normal population must be established. Such data are available for native speakers of English, but so far, the variability in the performance of the non-native speakers, if any, has not been investigated. Studies suggesting that a variability might exist in the performance on discrimination tasks between the native and non-native speakers were presented.

The purpose of the present study was to examine the effects of time compression on the intelligibility of English CNC monosyllabic words, specifically, the N.U. Auditory Test No. 6, among native speakers of Spanish and Indo-Dravidian languages who were proficient in English. The Indo-Dravidian language groups were chosen because of the personal interest and the professional needs of the experimenter in the audiological evaluation of the multilingual population in India. Spanish was chosen to meet the needs of audiologists in evaluating Mexican-Americans who constitute a sizeable proportion of the population in the south-western parts of the United States. In addition, since Spanish is considered to be more similar to English than are the Indo-Dravidian languages, consideration of these two language groups permits a comparison of the perceptual difficulties of non-native speakers of English whose native languages vary in their similarities to English.

The specific questions posed were:

(1) Will the various degrees of time compression have a differential effect on the intelligibility scores among subjects who use English as a second language as compared to native English speakers?

(2) Will there be a difference in the intelligibility scores as a function of the native language of the subjects?

(3) Will there be an interaction between the subjects' native language and time compression levels, between language and sensation levels and between language, time compression and sensation levels?

CHAPTER II

REVIEW OF LITERATURE

Literature pertaining to the present investigation includes studies utilizing cross-language stimuli with the monolingual and bilingual subjects and the studies on time-compressed speech with adult subjects.

Cross-language Studies

Reference has been made in the literature to the effect that the listener's native language affects perception of the stimuli in a foreign language. Moser and Dreher (1955) observed that the complaints received from the countries using the phonetic alphabet adopted by the International Civil Aviation Organization, appeared specific to the languages used in the respective countries.

Several studies on the aural comprehension of the bilingual persons' second language have evolved out of concern for educational achievement among children.

Carrow (1957) compared monolingual and bilingual children on a number of language achievement skills. Significant differences between the two groups were found on skills such as hearing vocabulary, but not on skills like silent reading.

In a subsequent study, Carrow (1971) compared the comprehension of English and Spanish in 99 children with Mexican-American surnames.

They were examined with an Auditory Test for language comprehension in English and Spanish. Though the children seemed to know English well, in specific areas they were found to be deficient in both languages. Since the subjects' surname alone was used as selection criterion and in the absence of supporting evidence that they were indeed bilinguals, it may be surmised that not all of the children were bilingual.

In comparing Spanish speaking children from low economic areas with English speaking children from similar backgrounds, Arnold and Wist (1970) used an auditory discrimination test consisting of 40 pairs of English words. They found the performance of the Spanish speaking children to be inferior to the English speaking children.

The chief concern of the preceding studies has been to analyze the educational problems of the bilingual children and to utilize the results in planning remedial programs.

Cross-language studies with adult subjects have utilized meaningful words, phonological sequences and synthetic stimuli. One of the studies designed to use meaningful words as stimuli was by Black and Tolhurst (1955) who had English, French and American naval officers record words from an American multiple-choice intelligibility test. Following the recording, the officers listened to the recorded stimuli. It was observed that each group of listeners performed best when the speakers were of their own nationality. The French speakers were relatively unintelligible to all three groups, although they had received supervised practice in reading. It is likely that poor discrimination of the French was due to their poor knowledge of English.

In a second study, using recorded words from a multiple-choice intelligibility test, Black and Hast (1962) obtained measures of binaural reception of words from three groups of subjects. One group had normal hearing and the second group had a mild hearing loss; both groups were comprised of native Americans. The third group consisted of foreign students presumably with normal hearing, but with limited comprehension of English. The experiment was designed to test if two channel recording facilitated comprehension to a greater extent than a single channel recording. The results indicated that the two channel recording benefited the foreign students to a significant degree, but not the native Americans thereby implying that with the additional cues, non-native speakers improved in their discrimination.

Although using lexical items as stimuli, Goto (1971) focused his attention specifically on sounds not found in the native language of the bilinguals. Minimal paris such as play/pray and collect/correct were presented to American and Japanese subjects. Each subject had initially recorded the 8 stimulus words alternately with some nontest stimuli. The subjects indicated on an answer sheet which of the two sounds, /l/ or /r/ they heard. From a qualitative analysis of the data, it was concluded that the Japanese were poorer than the Americans in the discrimination of the segments, /l/ and /r/ presumably because they do not discriminate between these sounds in their own language.

In the research with the bilinguals, phonological sequences consisting of sounds novel to one or both groups of subjects have also been used as stimuli. Sapon and Carrol (1957) presented a set of nonsense syllables to native speakers of Japanese, Spanish and English.

superiority of bilinguals was found limited to the segments of the second language they were learning and it did not extend to all unfamiliar phonological (Davine, Tucker and Lambert, 1971). Politzer and McMahon (1970) found that in discriminating between phonological sequences in their native and foreign languages, monolingual and bilingual Mexican-American children performed best when the stimuli consisted of sound sequences from their respective native languages.

It seems reasonable to ask whether poor discrimination of unfamiliar speech sounds may not reflect poor discrimination ability in general. The evidence provided by Miyawaki et al. (1973), suggests that such a contention may not be justified. They demonstrated that poor discrimination of speech sounds is not correlated with poor discrimination of nonspeech stimuli. Their experiment was based on the acoustic similarity between the segments, /r/ and /l/, the only difference between them being the onset and transition of the third formant. In /r/, the third formant has a low onset followed by a rise; in /l/, it has a high onset followed by a decline. Synthetic stimuli, ranging between these two extremes, were prepared to serve as speech stimuli. The third formant in isolation served as the nonspeech stimuli. Both types of stimuli, speech and nonspeech, were presented to 13 American and 21 Japanese subjects. The stimuli were presented for both absolute identification as well as discrimination. In the latter, the subjects' task was to pick out the odd one among the three stimuli presented. The number of correct responses were plotted as a function of the position of the third formant. American subjects discriminated best at the segmental boundary as indicated by a peak in the function, but the Japanese showed no such peak in the function, which remained low throughout. A difference in the performance of the two groups was not evident when non-speech stimuli were used.

The studies reviewed in this section generally reveal some difficulty in discrimination of phonetic differences not found to be constrastive in the listener's native language. It must be pointed out, however, that these studies have several drawbacks. The nature of the test environment, the presentation level of the stimuli and objective measures of competency in the second language have not been reported. These factors may affect the validity of the results. The extent to which the results can be generalized is also limited because many of the studies did not report the age and the hearing sensitivity of the subjects.

Studies on Time-Compressed Speech

Research on time-compressed speech may broadly be categorized into those dealing with the stimulus variables and those dealing with listener variables.

Stimulus Variables

The rate, redundancy and the complexity of the stimuli are several of the stimulus variables that have been explored.

Rate: Several studies have been reported on the effect of the rate of speech on comprehension utilizing both connected speech and monosyllabic words as stimuli.

The nonsense syllables were composed of speech sounds from English, French, Spanish, Portuguese, Italian and Russian. Each set of stimuli consisted of a stimulus word followed by four alternatives. The subjects, who had been instructed in their respective native languages, indicated which of the four alternatives matched the stimulus word. The authors concluded that the errors were non-random and that perceptual errors can be predicted from prior knowledge of the listener's native language. Analysis at the segmental level disclosed that the Spanish speakers did not confuse obstruents with continuants, such as perceiving /ǥ/ for the stimulus /g/, an error frequently committed by the English and the Japanese. Analysis at the feature level revealed that perceptual errors of duration were more prevalent among the English than among the Japanese or the Spanish. Other reports on perceptual errors at the feature level include greater confusion in the perception of aspiration among English speakers than among Hindi speakers when provocalic obstruents /p, t, k, b, d, g/ served as the stimuli (Singh, 1966). Similarly, comparing English, a language with two categories of voiced obstruents and Thai, a language with three categories of obstruents, Abramson and Lisker (1968) concluded that the ability to detect small differences along a physical continuum was influenced by the native language of the listeners.

Employing phonological sequences from Russian, a language foreign to both monolingual and bilingual subjects Rabinovitch and Parver (1966) concluded that bilinguals had superior ability in discrimination. However, few studies in the literature attest to this statement. In a group of children receiving bilingual and monolingual instruction, the

Fairbanks et al. (1957a), observed the variation in comprehension as a function of the rate of speech. Connected speech recorded by a male speaker was compressed by 0, 30, 50, 60 and 70% through an electromechanical apparatus described by Fairbanks et al. (1954). The stimulus was presented bilaterally through Permoflux PDR-10 earphones with 1505 cushions. The subjects were a group of young adult trainees at the Chanute Air Force Base. The results showed that with 60% time compression, the response was 50% correct of the maximum and with 50% time compression, the response accuracy was close to 90%. In general, with increasing rates, there was a corresponding decrease in comprehension. Similar conclusions were reached by Goldhaber and Weaver (1968) and Sticht (1968).

Of importance to clinical audiology, are the following studies utilizing monosyllabic words. Using the phonetically balanced words described by Egan (1948), compressed to 0, 36, 53 and 59%, Sticht (1968) tested a group of Army inductees, in a classroom environment. Intelligibility was found to decrease with an increase in rate of compression. Neither the methods nor the instrumentation employed to compress the stimuli were reported. Apart from the fact that the PB-50 word lists have received limited use clincially in recent years, the results of this study are of questionable value in clincial audiometry because of the deviation of the experimental conditions from the routine clinical conditions: the stimuli in the experiment were presented through loudspeakers in an ordinary classroom whose ambient noise level was not reported. Further, since the sample consisted of only Army inductees, a highly select group, the results can only be generalized to a limited extent.

Also employing monosyllabic words, Sticht and Gray (1969) compressed the CID W-22 words at 0, 36, 46 and 59% with the electromechanical sampling procedure. Presenting the stimuli to a group of normal young and aged adult subjects and to a group of subjects with sensorineural hearing loss, they found that discrimination ability was insignificantly affected by auditory sensitivity. The results also indicated that discrimination ability of the aged was poorer than that of the younger subjects, the magnitude of the difference increasing with the amount of time compression. The sample size in this study was not large enough to establish normative data for clinical purposes. Also the W-22 word lists have been found unsatisfactory in testing the discrimination ability of a clinical population (Carhart, 1965).

Pointing out the drawbacks of the earlier studies, Beasley, Schwimmer and Rintelmann (1972) undertook to establish normative data for clinical utility by employing time-compressed CNC monosyllables, the N.U. Auditory Test No. 6 described by Tillman and Carhart (1966). Speech compression was achieved through the electromechanical apparatus devised by Fairbanks et al. (1954) and modified by Zemlin (1971). The compression rates used were 0, 30, 40, 50, 60 and 70% and the stimuli were presented at 8, 16, 2[illegible], and 32 dB sensation levels. The subjects, 96 normal young adults, were randomly assigned to six groups corresponding to each rate of compression. Each subject received four lists of words at a specific percentage of compression at each sensation level employed. The results indicated that intelligibility decreased as the rate of compression increased, with a dramatic breakdown at 70% compression. In addition, it was observed that higher sensation levels, offset the adverse effects of compression on intelligibility.

In a subsequent study, Beasley, Forman and Rintelmann (1972) gathered data at 40 dB sensation level, a level at which discrimination is often tested clinically. The test stimuli and the experimental conditions were identical to those employed by Beasley, Schwimmer and Rintelmann (1972). The results followed the same trends as previously reported, i.e., intelligibility decreased with an increase in the magnitude of compression, a significant breakdown being seen at 70% compression.

The merits of the two studies described above (Beasley, Schwimmer and Rintelmann, 1972; Beasley, Forman and Rintelmann, 1972) lies in the fact that their experimental conditions were similar to those normally employed in a clinical setting. Hence, their data may be used for comparison with an abnormal population. However, in the absence of specific mention regarding the linguistic background of their subjects, the reader had to assume that they were monolingual native speakers of English.

To summarize, it appears from the above studies that there is a positive correlation between higher rates of compression and decrease in intelligibility, irrespective of the nature of the stimulus used.

In comparing studies in which compression rates were used as independent variables, it should be pointed out that the resultant rate of compression is function of the original rate. Thus, two different studies reporting the same compression ratios may have employed non-identical rates on account of the differences in the original rate. Further, differences in expressing rates may occur. The amount of compression may be specified by the percentage of the original recording time that is saved or the time remaining after compression. Standard methods of expressions are needed.

With respect to time-compressed speech, it may be asked whether it is the increased rate itself or the distortion caused by increased rates that is detrimental to comprehension. Sticht (1969) attempted to separate the two by restoring the time-compressed speech to the original rate, reasoning that through this procedure, the distortion caused by compression would still be present in the signal, but the rate would no longer be a variable. Three groups of subjects listened to the stimuli, factual material related to Military service, time compressed through Eltro Information Rate Changer. The results under the three experimental conditions--uncompressed, 40% time compressed, and 40% time compressed with rate restored--indicated that signal distortion was not as detrimental to comprehension as the rate. A drawback of this study appears to be in not specifying whether the stimuli were of equivalent difficulty.

Redundancy: If time compression is not detrimental to comprehension, then within the same duration, if the stimulus redundancy were increased through repetition, is it possible to increase comprehension? To answer this, Fairbanks et al. (1957b), employed single and double presentations at two time compression ratios, 0 and 50%, with a group of Air

Force trainees. The results indicated a slight superiority of the double over the single presentation.

In a second study directed toward a similar purpose, Fairbanks et al. (1957c), employed two versions of the same message, a short (the original) version and a long (the augmented) version. The latter was obtained by splicing parts of the stimulus words into the tape. The effectiveness of the augmented version was seen in scores on a multiple-choice test; it was also found, rather unexpectedly, that there was a decrease in the scores to the unaugmented version.

Yet another aspect of redundancy was investigated by Sticht (1969). Recorded words from the PB-50 lists were arranged adjacently so as to make up two short stories. Since the "stories" were independently pronounced words, there were no cues of inflection or phrase. In a different version, the sequence of words was read normally. Finally, the words were presented in random order. The cloze technique was used to get a measure of the dependent variable. The technique involves deleting portions of a passage, written or oral, and asking the subject to provide the missing words. It was found that with the increase in the number of cues, inflectional and syntactic, there was an improvement in the subjects' ability to guess the missing word.

Other research in relation to time compression are effects of training and correlates of listening ability. Voor and Miller (1965) increased the rate of speech in successive trials and used the scores on a multiple-choice test to observe any improvement due to training.

Five complete stories compressed through a Tempo Regulator were used as training material. The results indicated that in subjects with no previous exposure to compressed speech, practice increased comprehension. Similarly, Orr et al. (1965) found that with several weeks of training with material presented at 475 wpm, an improvement of 29.3% could be achieved. The rates were successively increased from 325 to 475 wpm in steps of 25 wpm.

Friedman and Johnson (1968) investigated the correlates of listening comprehension of normal and compressed speech. The subjects were native speakers of English with no prior experience with compressed speech. With a Tempo Regulator, three rates of compression, 250, 325 and 450 wpm were played to the subjects in groups and some individually. Among the different tests, a test developed to evaluate semantic relations, the Best Trend Name Test, was found to be the best predictor.

Reading and listening were found to be correlated in a study by Sticht (1968). Forms A and B of a comprehension test each served as the reading and the listening tests. No significant differences in reading and listening were found. It was speculated that general language deficiency may cause lower scores in both normal and compressed speech.

<u>Variables Related to the Listener</u>

<u>Sex:</u> Golhaber and Weaver (1968) reported significant sex differences in the comprehension of time compressed speech. The stimuli were three messages related to the history of radio and TV. The messages were

recorded by a male radio announcer and compressed at 175, 325, 375 and 425 wpm., through a Tempo Regulator. The subjects 240 college students, heard two passages of time compressed speech. Comprehension scores on a multiple-choice test revealed the male subjects had higher scores than the female subjects at all four rates of compression and at three levels of stimulus difficulty. The authors speculate that the sex differences in comprehension might have been due to the greater appeal of the stimuli to the male than the female subjects. Sex differences were found unrelated to the comprehension of time compressed speech by other investigators (Foulke and Sticht, 1969; Orr and Friedman, 1964).

Intelligence: Sticht (1968) compared the comprehension scores obtained by Army inductees of high, low and average aptitude as measured by the Armed Forces Quantification Test. Forms A and B of a comprehension test, each served as the reading and listening test. Significant differences between the low and the average groups were found, the differences favoring the average group. The subjects with higher aptitude showed a greater decrement in their performance as the rates increased. Similar results were reported by Fairbanks et al. (1957c). In reviewing studies on compression, Foulke and Sticht (1969) attribute the lower scores of the high aptitude men to their higher scores at the outset. Another explanation would be the regression effect, whereby two groups chosen initially for their extreme scores would regress toward the population mean. Thus, whereas the low scorers show an improvement the high scorers appear to have become worse.

Educational achievement: Watts (1971) concluded that Army Officers with higher education performed better than the NCO's who had less than a college education. The stimuli were lecture material that was normally given orally with visual illustrations. The validity of the findings is increased through the use of a comparative group of officers who listened to similar stimuli, but without time compression.

Second language comprehension: Johnson and Friedman (1971) studied the effect to time compression on the perception of stimuli in the second language of the bilinguals. The subjects were 12 students enrolled in a Russian language class. The stimuli, 60 sentences in Russian, were presented under 3 experimental conditions: (1) a gap of one second duration was inserted between two parts of a sentence such that the gap coincided with the structural division; (2) non-structurally segmented in which the gap did not coincide with any structural boundaries; (3) non-segmented or normal. The segmented versions were time compressed by 30%. The results showed that the effect of time compression on the perception of stimuli in the second language was negligible. The authors attribute the insignificant effect of time compression to the low rates of compression employed and also to the temporal spacing. Relevant information lacking in the report are the presentation level of the stimuli and the instrumentation employed for time compressing the sentences.

Changes in the auditory system: Studies on presbycusic subjects are also included in this category because changes in the central nervous system are generally associated with the aging process.

One of the earliest attempts at audiometric evaluation through time-compressed speech was directed at discriminating between normal and presbycusic subjects by varying the intensity and the syllabic rate of 'short, significant sentences' (Calearo and Lazzaroni, 1957). These sentences were recorded at 140, 250 and 350 wpm. Articulation curves for both groups of subjects were generated. For the normal subjects, the average threshold shift was between 5 and 10 dB. The shape of the articulation curve, however, remained normal. The findings for the presbycusic group were significantly different. The threshold shift was as much as 30 dB at 250 wpm; at 350 wpm, the criteria for threshold could not be met at any intensity level. Further, it was found that in a group of patients with temporal lobe lesions, poorer articulation curves were generated when the time-compressed sentences were presented to the ear contralateral to the site of lesion.

deQuiros (1964) employed accelerated speech with the following groups of subjects: 20 with normal hearing, 15 with peripheral hearing loss, 7 with presbycusis and groups of adults and children with various central disorders. The stimuli consisted of 'abstract' sentences of approximately 10 words each for the adult subjects and 'concrete' sentences of equivalent length for the children. The rates of presentation were 140, 250 and 350 wpm., achieved by the same methods of acceleration as those adopted by Calearo and Lazzaroni (1957). The articulation scores for the sentences were evaluated in relation to the shape of the articulation curve, speech detection threshold, speech reception threshold and maximum articulation score. It was found that for the normal subjects all three speeds employed yielded similar articulation curves; any differences found were within a range of 10 dB. The speech detection threshold remained constant. With conductive lesions, the articulation curves were either similar to those of the normal subjects or they shifted to a higher intensity level. With cochlear lesions, results similar to those of normal were frequently obtained, but more often the maximum articulation score for the 350 wpm. presentation was lower than those obtained for the normal subjects. In the presbycusic group, a shift in the threshold of detectability for all three rates of presentation was common. Though the results of this study would imply that accelerated speech provided additional information in differential diagnosis and in identifying the site of lesion within the central nervous system, the small number of subjects within each category of the central disorders would preclude conclusive statements.

Calearo and Lazzaroni (1957), and deQuiros (1964) pointed out the feasibility of employing time-compressed (accelerated) speech clincially, but due to the inadequate description of their experimental procedures, such as the nature of the speech stimuli and the methods used to compress speech, confirmation of their findings through replication is not possible.

More recently, Luterman, Welsh and Melrose (1966) compared the performance of subjects with normal hearing and with sensori-neural hearing loss. CID W-22 word lists compressed by 10 and 20% by means of an electromechanical apparatus served as the stimuli. The results showed that intelligibility was adversely affected by compression, the pathological group performing poorer than the normal. Among the sensori-neural subjects, the younger subjects performed better than the aged. In a group of adults with noise induced hearing loss, Kurdziel (1972) found that these subjects showed a gradual decrease in discrimination as the degree of compression increased, with a precipitous drop at 70% compression levels. The performance of these subjects differed from those of the normal in that they required lower sensation levels for optimum performance at lower compression levels. At higher compression levels, such as 70%, the articulation curve reached a plateau at 24 dB sensation level. These studies point out that for time-compressed speech stimuli, responses of the pathological subjects deviate from those of the normal, thereby suggesting that further explorations of time-compressed speech stimuli with pathological subjects for diagnostic purposes is a worthwhile area of study.

In summarizing the findings on the variables related to the listener, the role of sex as an independent variable in time compression studies can probably be discounted. Further studies of intelligence and comprehension as related to time compression would seem necessary to state conclusively that superior intelligence does indeed interact with higher rates of time compression to interfere with comprehension. Similarly, further explorations of the interaction between time-compressed speech, bilingualism and pathological conditions within the auditory system are necessary.

Summary

In reviewing the literature, cross-language studies and research on time-compressed speech was discussed. Among the former, aural comprehension in a second language among children and perception of words and speech sounds in a foreign language among the adults were discussed. The majority of the evidence supports the contention that stimuli in a foreign language present difficulties in certain discrimination tasks. Perception of nonspeech stimuli in the same subjects did not present similar problems.

Increasing rates of time compression has been shown to be detrimental to comprehension, especially at the higher compression rates. Diagnostic implications of presbycusis and central auditory disorders were discussed. So far, however, compressed speech stimuli have not been employed with bilingual subjects to yield normative data which is essential for diagnostic purposes in a bilingual population. From the evidence available from cross-language studies, greater difficulties in perceiving compressed speech may be anticipated in persons with bilingual backgrounds, but definitive data in this respect are not presently available. The present study is designed to provide such information.

CHAPTER THREE

EXPERIMENTAL PROCEDURE

Subjects

The subjects were volunteers, who were young adult native speakers of Indo-Dravidian languages and Spanish speaking Mexican-Americans. There were 72 subjects per language group, for a total of 144 subjects. The age range of the subjects was between 16 to 28 years, with a mean age of 23 years and a median age of 23.47 years. Of the Indo-Dravidian speakers, 46 were male and 26 were female, with a mean age of 24 years and a median age of 24.42 years. The Mexican-American group consisted of 37 males and 35 females with a mean age of 22 years and a median age of 22.34 years.

Prior to inclusion in the study, each subject was required to pass a pure-tone audiometric screening test bilaterally, consisting of 250 through 8000 Hz tones presented at 20 dB HTL (ANSI, 1969) through earphones. In addition, the subjects were required to pass English proficiency tests, specifically, the Michigan Aural Comprehension Test and the Michigan English Language Proficiency Test.

Test Environment

The subjects were seated in a sound-treated room combination consisting of a single-walled (IAC 400 series) control room and a double-walled test booth (IAC 1200 series).

The ambient noise levels of the test room were measured according to the criteria specified by the American Standards Association for background noise in audiometer test rooms (ASA-S 3.1-1960). The levels recorded by means of a sound level meter (Bruel and Kjaer, 2203) are reported in Appendix A. The noise levels measured were sufficiently low as not to interfere with the test signals.

The pure-tone audiometer, the speech audiometer and the tape recorder were located in the control room. A window and a talk back system were located between the two rooms that permitted communication between the tester and the subject.

Instrumentation

A pure-tone audiometer (Beltone 15C) that drove earphones (TDH-39-10Z) housed in biscuit-type cushions (MX-41/AR) was used for pure-tone screening. For the recorded speech tests, a speech audiometer (Grason-Stadler, Model 162) was used to attenuate and amplify the signal from a tape recorder (Panasonic, Model RQ-706S). The speech stimuli were presented via the left earphone, with the right earphone covering the non-test ear, but unused. The procedure and instrumentation employed to check the calibration of the test instruments is reported in Appendix B.

Test Procedure

At the outset each subject received a pure-tone screening test, consisting of 250 through 8000 Hz tones presented at 20 dB HTL (ANSI 1969) through earphones bilaterally. The instructions given level began in 2 db steps with two words being presented at each step. The criteria to begin the attenuation was to have five correct responses out of six. The speech reception threshold was determined as the lowest level where both responses were correct minus 1 dB for every word repeated correctly below this level. Since the attenuator on the speech audiometer was calibrated in 2 dB steps, the speech reception thresholds with odd integers were increased by 1 dB.

To obtain speech discrimination scores, the subjects were assigned randomly to one of the six time compression conditions -- 0, 30, 40, 50, 60 and 70 percent compression. Each subject received four lists of the N.U. Auditory Test No. 6, Form B, at 8, 16, 24, 32 and 40 dB sensation levels (re: SRT), but within the same compression condition. For each subject, the lists presented at 8 and 40 dB sensation levels were identical. The order of presentation of the lists and sensation levels were randomized for each subject. Instructions given to the subjects were as follows:

> You are now going to hear, 'You will say, 'please,' 'You will say, 'chair,' etc. I want you to write down the last word you hear, in the space provided on the answer sheet. For example, if you hear, 'You will say, 'please,' just write the word 'please.' If you hear, 'You will say, 'chair,' just write the word 'chair.'
>
> The words will sound as if they are spoken rather fast. So, listen carefully and write down whatever you think you heard. In case you miss any word, leave the space blank and go on to the next. You will hear five lists of words altogether. Some lists will be loud and some will be soft. Within each list, if the words start out being loud, they will remain loud throughout that list and if they start out being soft, they will remain soft throughout that list.

were:

> You are going to hear some tones which will sound like . . . . The tones will be first presented to one ear and later to the opposite ear. The tones will be very soft. So listen carefully and raise your hand as soon as you hear the tones and lower it as soon as you stop hearing the tones.

The speech reception threshold was obtained via the left earphone placed on the test ear, which was chosen randomly. The subjects were instructed as follows:

> You are now going to hear words like 'airplane,' 'ice cream.' I want you to repeat the words you hear. The words will be comfortably loud at first, but they will get softer and softer. Sometimes you may not be sure of what you heard, but try to guess and repeat whatever you think you heard. You will hear the words in your right (left) ear only.
>
> To give you some practice, I will now read out the words. I want you to repeat them after me. The words you hear now will be the same as the ones you will hear later.

Speech reception thresholds were obtained with tape recorded words from the CID Auditory Test W-1 lists D and E. A male speaker with General American Dialect recorded the words such that the two syllable peaks of each word drove the needle of the vu meter to the same deflection within ± 1 dB as that produced by a 1000 Hz calibration tone on the same tape.

To obtain the speech reception thresholds, the procedure described by Rintelmann et al. (1973) was adopted. Initially, the subject was familiarized with the spondees. The words were then presented at 30 dB HTL through a single earphone. Two words were presented at each level. If both words were repeated correctly, the presentation level was attenuated by 10 dB. Attenuation from this

The stimuli used were identical to those employed in a previous study by Beasley, Schwimmer and Rintelmann (1972).

The subjects were administered the English Proficiency Tests--the Michigan Aural Comprehension Test and the Michigan Test for English Language Proficiency. The former was administered by means of tape recorded stimuli. In the latter test, which consists of three subtests, only the Grammar and Vocabulary subtests were administered. The subtest, Reading Comprehension was not administered because it is considered to have low reliability and to contribute little to the information gained from the other two tests. The scores obtained on the subtests of Grammar and Vocabulary were converted to percentages by employing the conversion formula used at the English Language Center, Michigan State University. The conversion formula, based on the original formula, is reproduced in Appendix C.

For each subject all testing was done in a single session with a short intermission between the presentation of the audiologic measures and the presentation of the English Proficiency Tests. The duration of each session was approximately two hours.

CHAPTER FOUR

RESULTS

In this chapter, the results obtained from the two experimental groups are presented for comparing the effects of language, the level of compression and sensation levels, on discrimination.

Analysis of the data is presented descriptively through means and standard deviations as well as inferentially, by means of multivariate ANOVA for repeated measures. The repeated measures were on the sensation levels. The two factors were arranged in a two dimensional table of 2x6 design. The mean discrimination scores obtained were the measures entered in the 12 cells. The F statistic was used in testing the statistical significance of the variance that could be attributed to the three main effects and the two-way and three-way interactions.

Effect of Native Language on Discrimination

The mean discrimination scores for the two language groups under the six compression conditions are presented in Table 1 and illustrated graphically in Figures 1 and 2. A comparison of the means for the two groups shows that the mean scores of the Spanish group are higher than the mean scores for the Indo-Dravidian group, except at the 0% compression level. The statistical analysis summarized in Table 2 shows that the main effect for language is significant at the 0.0001 level.

TABLE 1. MEANS ($\bar{X}$) AND STANDARD DEVIATIONS FOR THE SPANISH AND THE INDO-DRAVIDIAN SPEAKERS UNDER THE SIX COMPRESSION CONDITIONS AT THE FIVE SENSATION LEVELS

PER CENT COMPRESSION	8		16		24		32		40			
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	Total	$\bar{X}$ Total
0	65.67	14.26	78.5	11.28	86.33	9.64	88.33	8.39	93.17	5.62	412	82.4
	71.33	16.16	83.17	8.33	89.0	5.55	90.67	5.61	92.0	5.18	426.17	85.23
30	68.67	22.03	83.0	9.85	90.5	6.82	92.17	3.46	92.0	5.6	426.34	85.16
	68.0	23.63	76.67	17.91	87.67	10.71	87.17	10.56	88.5	9.03	408.01	81.6
40	46.17	19.09	63.33	15.31	81.67	9.75	86.0	7.23	89.67	5.31	366.84	73.36
	54.33	23.93	61.16	12.07	76.17	11.17	82.5	11.66	85.83	5.49	359.99	72.0
50	39.83	16.26	58.17	13.76	73.33	9.77	86.5	7.14	86.5	7.44	344.33	69.4
	41.83	22.21	58.0	11.15	73.5	13.96	81.67	9.67	81.33	10.06	336.33	67.26
60	30.83	17.75	49.67	18.42	70.83	13.41	77.83	11.67	83.83	8.15	312.99	62.5
	27.17	13.52	39.34	11.26	58.83	10.97	63.67	8.39	66.33	12.87	255.34	51.1
70	19.0	12.5	31.83	12.54	52.33	13.45	57.83	11.58	61.17	11.23	222.16	44.43
	12.0	20.46	18.33	17.18	31.5	19.71	34.33	18.05	37.33	27.39	133.49	26.69
Total	270.17		364.45		454.99		488.36		506.34		2084.66	417.25
	274.66		336.67		416.67		440.01		451.32		1919.33	383.88
$\bar{X}$ Total	45.02		60.75		75.83		81.43		84.39		347.44	69.49
	45.77		56.11		69.44		73.33		75.22		319.88	63.98

Note: Within each compression and sensation levels, the first rows of figures are for the Spanish speakers and the second rows are for the Indo-Dravidian speakers.

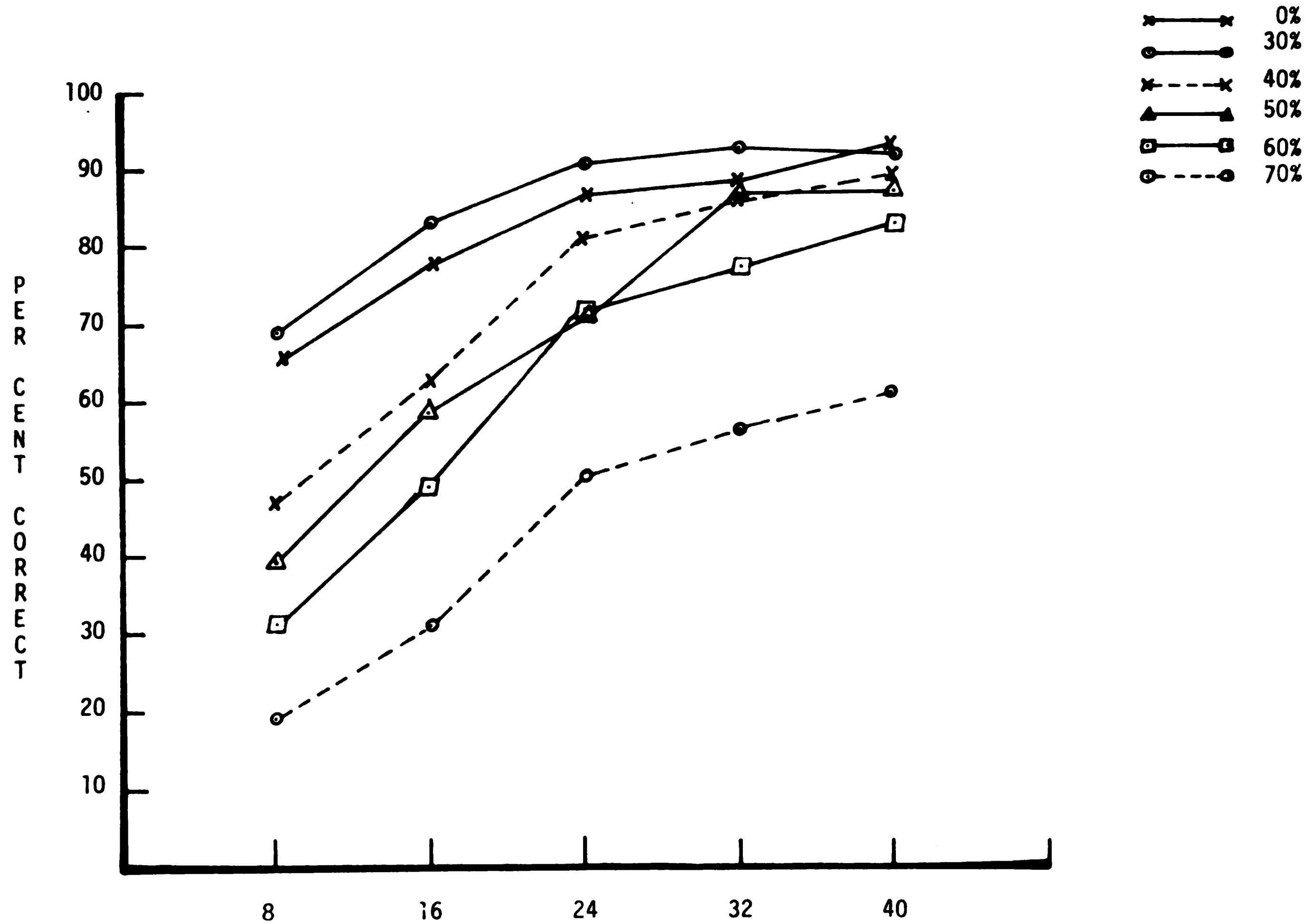

Figure 1.--Mean discrimination scores of Spanish speakers under 6 compression conditions at 5 sensation levels.

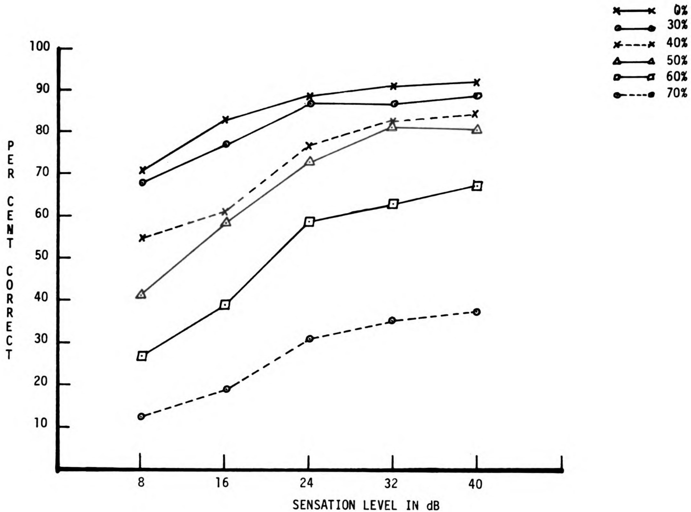

Figure 2.--Mean discrimination scores of Indo-Dravidian speakers under 6 compression conditions at 5 sensation levels.

TABLE 2. RESULTS OF THE MULTIVARIATE ANALYSIS OF VARIANCE FOR THE MAIN EFFECTS OF LANGUAGE, COMPRESSION LEVEL AND SENSATION LEVEL AND THE INTERACTION EFFECTS.

Source of Variation	d/f	Mean Squares	F-ratio	p
Language	1	5467.02	9.26	0.0029*
Compression	5	40254.76	68.19	0.0001*
Language x compression	5	1746.93	2.95	0.0145*
S: Language x compression	132	590.31		
Intensity	4	30356.21	382.8	0.01*
Intensity x compression	20	508.85	6.41	0.01*
Intensity x language	4	547.7	6.9	0.01*
Intensity x Language x compression	20	48.29	0.61	0.25
Error	528	79.3		

*Significant at the levels indicated

Although the performance of the Spanish group was in general, superior to the Indo-Dravidian group at all levels except at the 0% compression level, the mean differences between the two language groups were less than four percentage points (or two words) at 30%, 40% and 50% compression levels. Nevertheless, the F statistic for the interaction between language and compression is significant at 0.01 level. This interaction is illustrated in Figure 3.

Effect of Compression Level on Discrimination

In general, higher compression levels are inversely related to the discimination score; that is, increasing the amount of compression has a negative effect on discrimination. The main effect of compression shown in Table 2, is highly significant at 0.0001 level. However, it appears that the mean scores of the two experimental groups were differentially affected, i.e., while higher compression levels are detrimental to discrimination ability, the statement does not seem to be equally true for both language groups. This is indicated in the significant interaction between language and compression, which is depicted in Figure 3.

Effect of Sensation Levels on Discrimination

The mean discimination score for intensity averaged across compression levels presented in Table 1, indicated that with increasing sensation levels, there was a corresponding increase in the discrimination scores. In Table 2, the F statistic for intensity is shown to be significant ($p<0.01$).

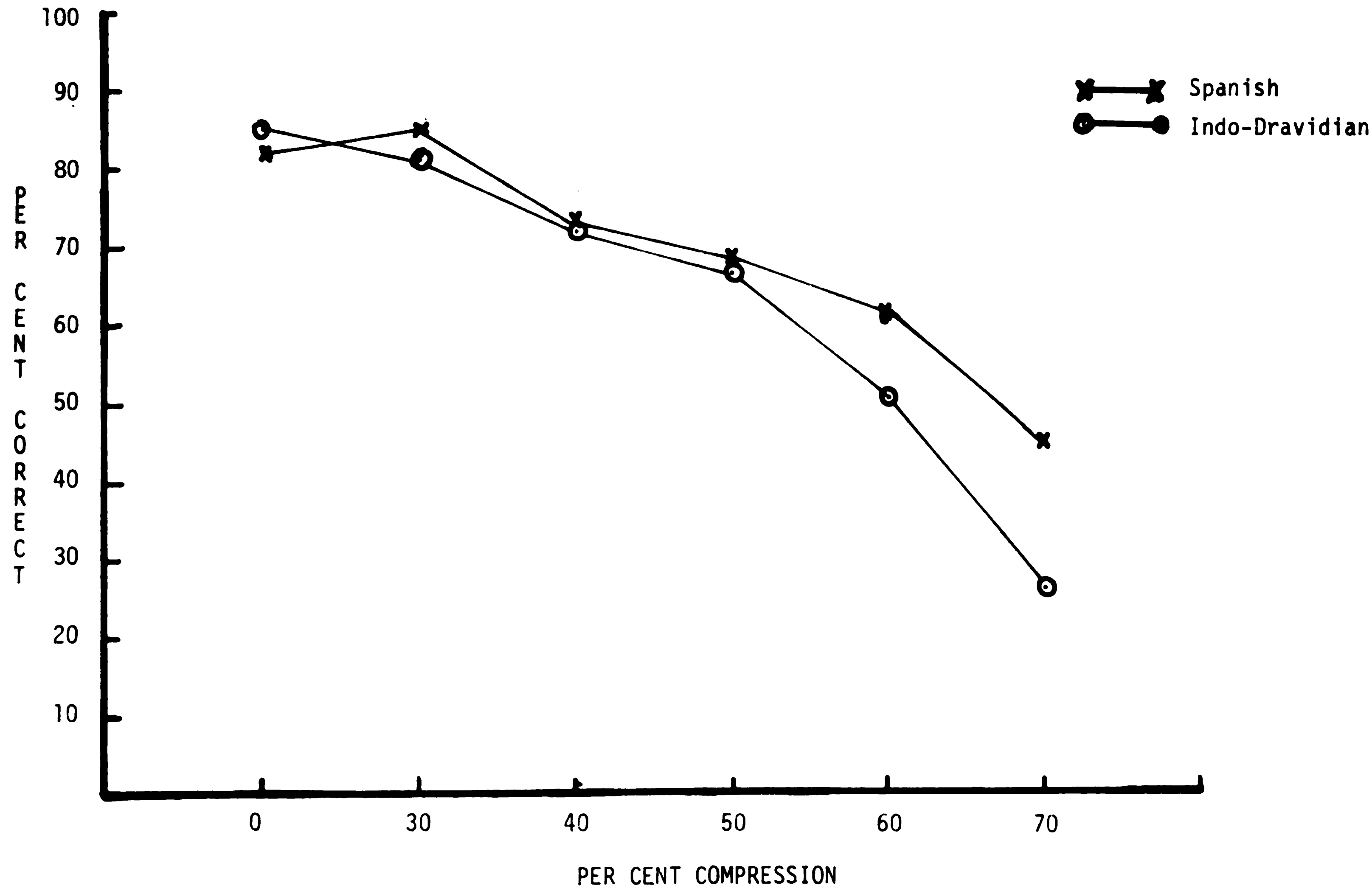

Figure 3.--Mean discrimination scores of the Spanish and the Indo-Dravidian groups under the 6 compression conditions across sensation levels.

Trend analysis was performed between the various levels of intensity (Kirk, 1968; Winer, 1971). This analysis indicated the quadratic trend to be the most significant ($p<0.01$). This means that with increasing sensation levels, there was a corresponding increase in the mean discrimination score upto a certain level. Referring to Figure 4, it may be seen that this level was reached at 24 dB sensation level. Beyond this level, the effect of sensation level is minimal. Due to the significant quadratic trend, it may be predicted that at sensation levels higher than those employed in the present study, the mean discrimination scores would either show a downward trend or remain at the maximum levels reached. In addition, it may be predicted that at sensation levels lower than those employed in this study, the mean scores would show a downward trend.

The effect of intensity, however, was not identical for both language groups. As illustrated in Figure 4, there was an interaction between language and intensity. The F statistic for the interaction between intensity and language shown in Table 2, was statistically significant ($p<0.01$). Furthermore, there appears to be a significant interaction between intensity and compression.

Trend analysis performed to study the nature of these interactions revealed that the differences in the linear trend was most significant ($p<0.01$). This means that the scores achieved at the five sensation levels did not show a decline at an uniform rate. The spread of the mean scores at 0% and 30% was not as great as it was at 60% compression. This is illustrated in Figure 5. Similarly, the two groups

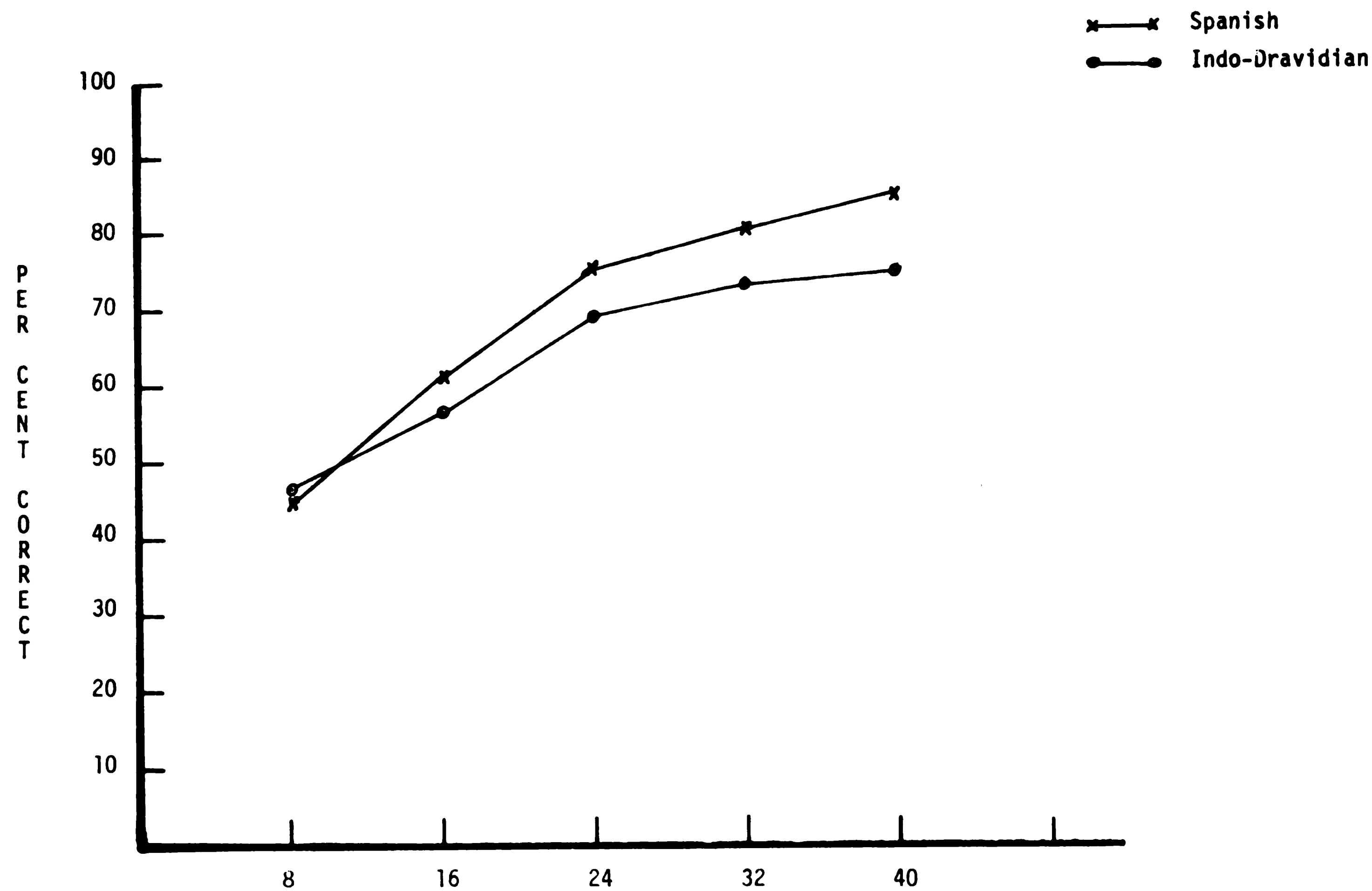

Figure 4.--Mean discrimination scores of the Spanish and the Indo-Dravidian groups at the 5 sensation levels.

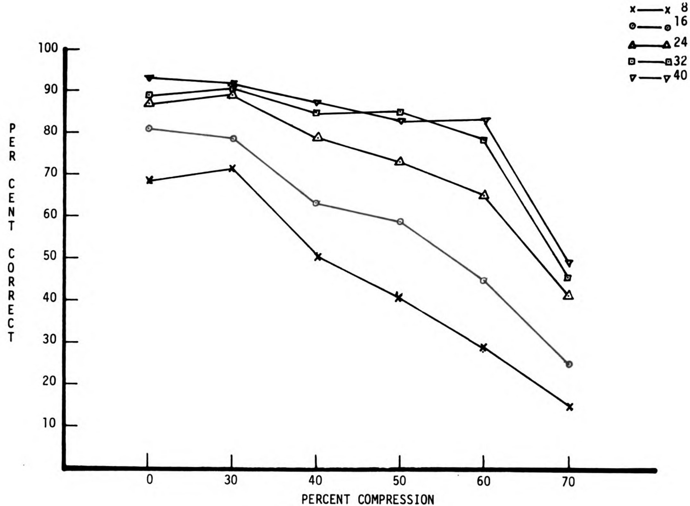

Figure 5.--Mean discrimination scores averaged across language groups.

did not benefit at uniform rates with increasing sensation levels. The range of the mean scores was greater at 40 dB sensation level than it was at 8 dB sensation level.

English Proficiency Scores and Language Groups

The mean scores for the two experimental groups on the Aural Comprehension Test and the Michigan Test for English Language Proficiency are presented in Table 4 and illustrated in Figures 6 and 7. The Spanish speakers' scores were slightly higher on both tests and within all compression conditions, except at 0% compression, whereby the Indo-Dravidian subjects scored higher than the Spanish speakers on both tests. The maximum difference in the mean score between the two groups for aural comprehension was 7% and the difference in the mean for grammar and vocabulary was 5%. Both these differences occurred within the 60% compression level. The overall difference between the two groups in aural comprehension was 2.36% and the difference in grammar and vocabulary was 2%. When the scores on both tests are combined, the Spanish speakers obtained a mean score of 94.86% and the Indo-Dravidian speakers got 92.78%. These mean differences are not considered significant for interpretations of the discrimination scores.

TABLE 3. MEANS AND STANDARD DEVIATIONS FOR THE SPANISH AND THE INDO-DRAVIDIAN SPEAKERS ON TEST OF AURAL COMPREHENSION AND TEST OF ENGLISH LANGUAGE PROFICIENCY.

PERCENT COMPRESSION	Aural comprehension $\bar{X}$	Aural comprehension SD	Grammar & Vocabulary $\bar{X}$	Grammar & Vocabulary SD	$\bar{X}$ Total
0	94.91	4.79	95.5	4.6	95.20
	95.75	3.76	95.75	3.64	95.75
30	95.08	3.44	96.33	2.93	95.70
	92.5	5.53	94.5	5.31	93.5
40	94.16	5.35	94.41	4.81	94.28
	93.25	4.51	93	4.95	93.12
50	94.08	4.27	94.75	4.86	94.41
	92.08	5.45	92.91	4.16	92.49
60	93.66	5.22	94.91	4.66	94.28
	86.66	2.7	89.91	3.94	88.28
70	95.33	4.51	95.25	4.71	95.29
	92.83	6.47	93.08	6.12	92.95
Total	567.21		571.15		569.21
	553.07		559.15		556.71
$\bar{X}$ Total	94.53		95.19		94.86
	92.17		93.19		92.78

Note: Within each compression condition, the first row of figures are for the Spanish speakers and the second row are for the Indo-Dravidian speakers.

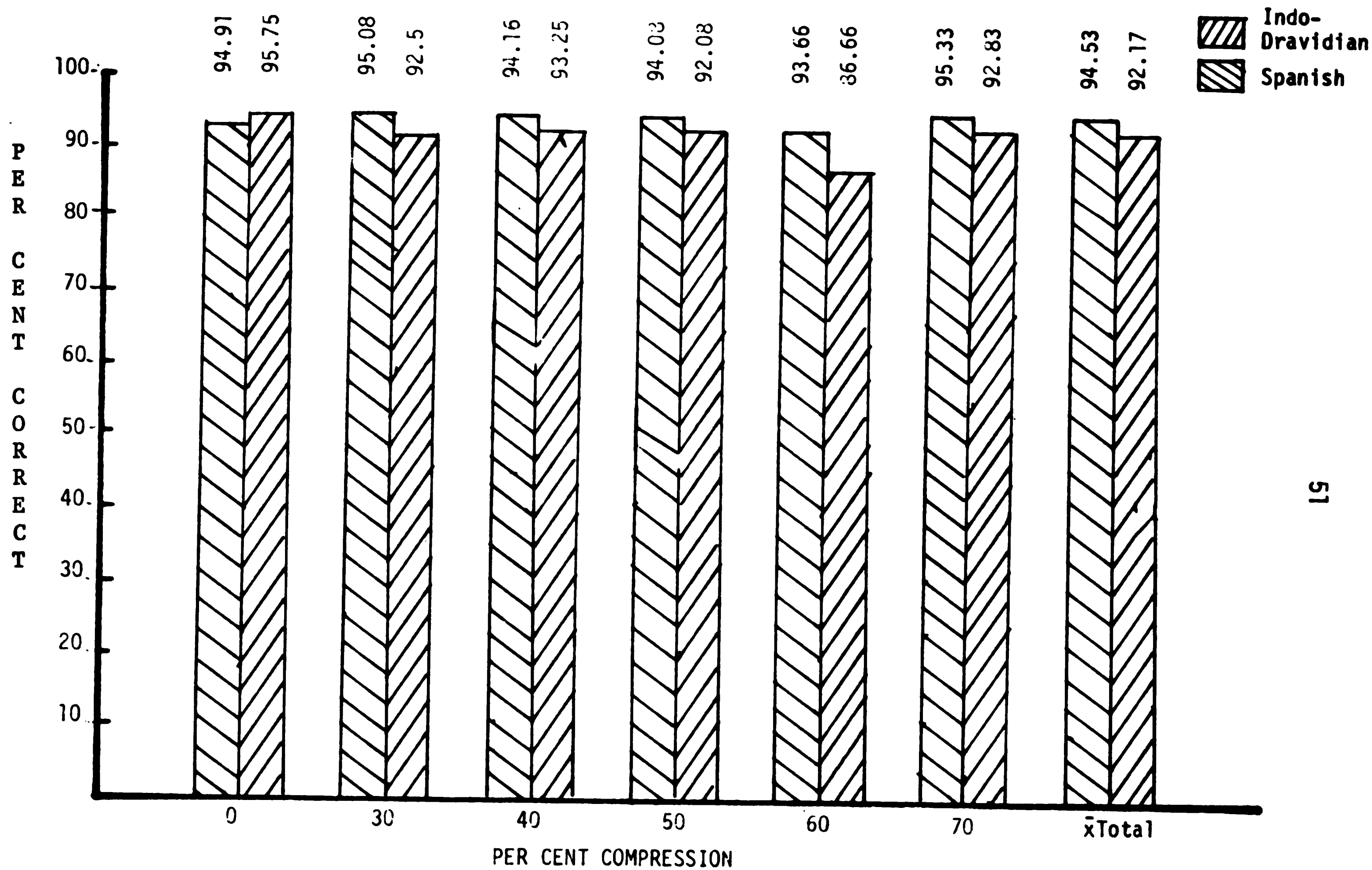

Figure 6.--Mean scores on the Test for Aural Comprehension for the Spanish and the Indo-Dravidian speakers.

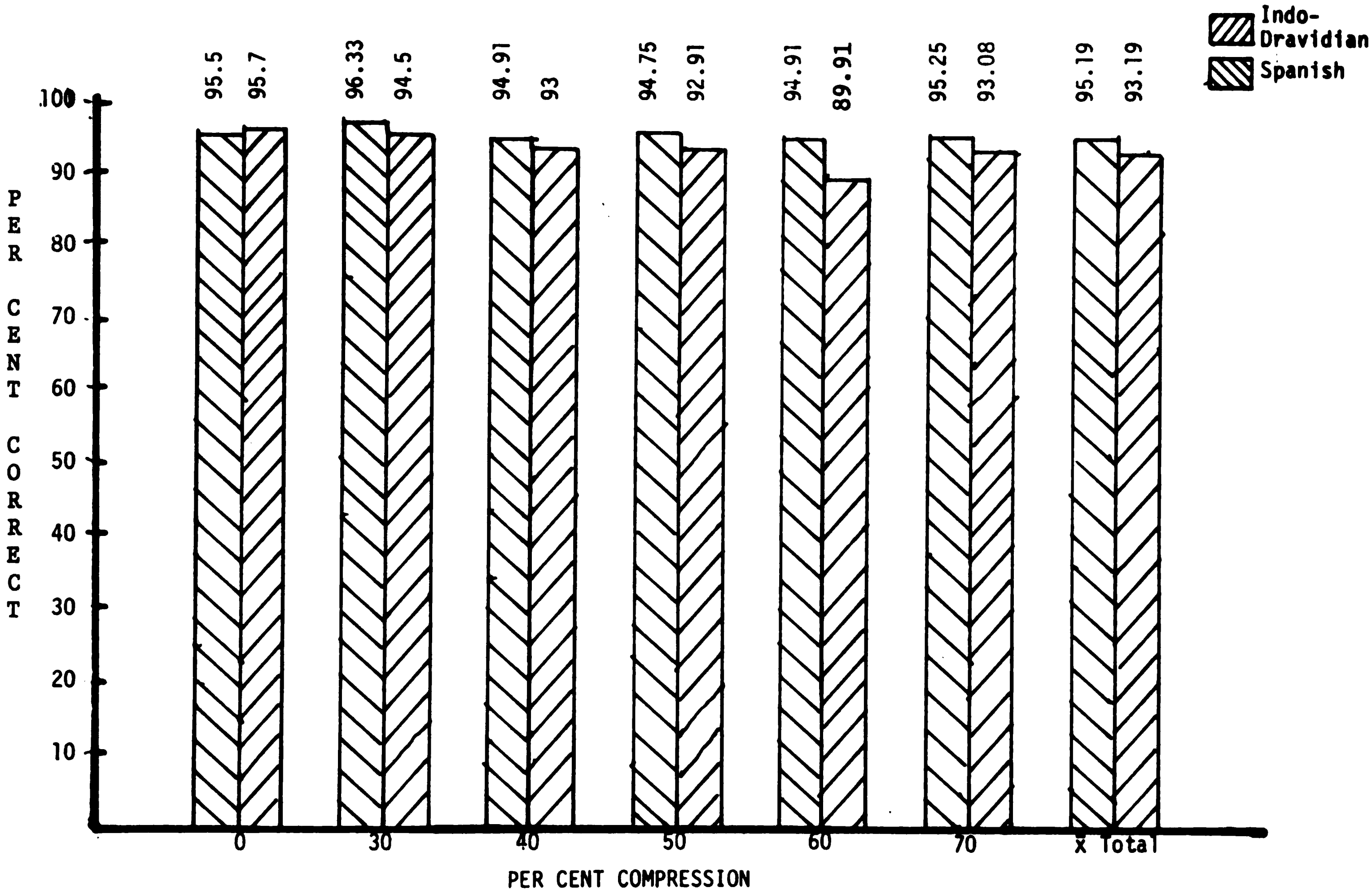

Figure 7.--Mean scores on the English Proficiency Test for the Spanish and the Indo-Dravidian speakers.

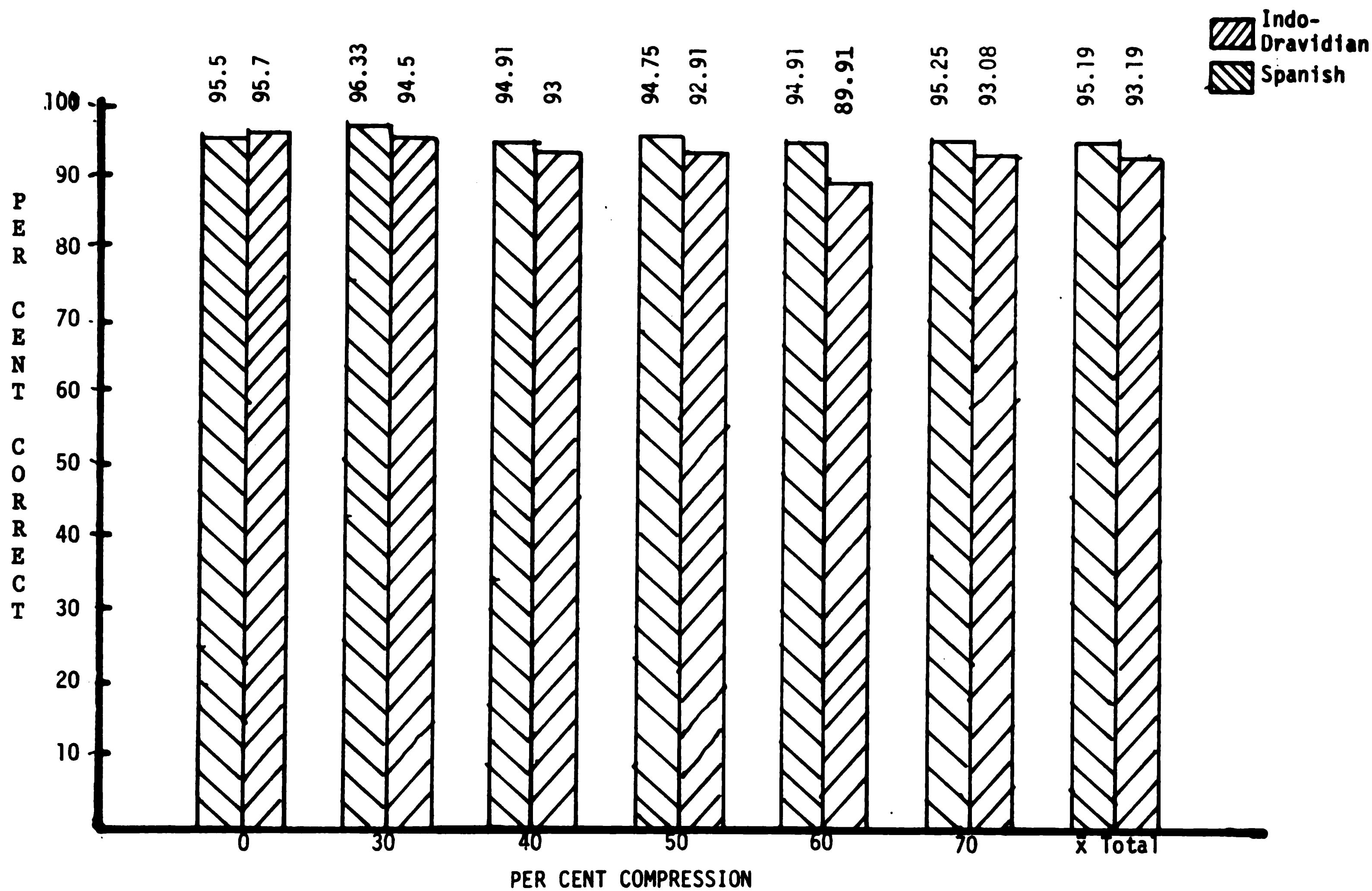

Figure 7.--Mean scores on the English Proficiency Test for the Spanish and the Indo-Dravidian speakers.

CHAPTER FIVE

DISCUSSION

The results of the present investigation indicated that significant effects upon the discrimination abilities were observed with respect to native language, time compression and sensation levels. The effects of these variables shall be discussed individually.

Effect of Native Language upon Discrimination

There was a significant difference between the two language groups in their discrimination scores under the various time compression conditions utilized in this study. Though discrimination scores progressively deteriorated for both groups as the levels of compression increased, a significant interaction effect indicated that time compression did not have identical detrimental effects on the two language groups. This differential effect may be explained in several ways.

First, it may be recalled that the stimulus words were recorded by a speaker with General American Dialect. It is likely that the Spanish speakers were more accustomed to the speaker's dialect than the Indo-Dravidian subjects who constituted a heterogenous group with respect to exposure to the American dialect. Lehiste and Peterson (1959) pointed out that with other significant factors such as hearing sensitivity, training and intelligence held constant, the difference between two listeners may be attributed to their facility in interpreting the dialect of the speaker. To lend further support to this argument, Lane (1963) found that under adverse listening conditions, such as low pass filtering and masking, speech with foreign accent was less intelligible than speech without foreign accent.

Second, of the two language groups utilized, Spanish belongs in the same general family as English. The Indo-Dravidian group consisted of speakers of the Indic and the Dravidian languages. Whereas the Indic languages belong to the same language family as Spanish and English the Dravidian languages do not. Lehiste and Peterson (1959) postulate that the dialect intelligibility ratio, D, might be higher for a listener whose language belongs in the same general language family as that of the speaker, than for a listener whose language is alien to that of the speaker. If this hypothesis is correct, then it may be suggested that the Dravidian subjects might have experienced greater difficulty in the discrimination task than the Indic speakers and hence contributed to the lower mean scores of the Indo-Dravidian group.

If the two arguments presented above are valid, then it may be anticipated that the native speakers of English would score higher than either of the bilingual groups employed in the present study. Data from the native speakers of English from previous studies (Beasley, Schwimmer and Rintelmann, 1972; Beasley, Forman and Rintelmann, 1972) presented in Tables 4 and 5 show that the scores of the native speakers are indeed higher than those of the non-native speakers at all

TABLE 4. MEAN DISCRIMINATION SCORES FOR THE NATIVE SPEAKERS OF INDO-DRAVIDIAN AND ENGLISH FOR EACH CONDITION OF TIME-COMPRESSION AT FIVE SENSATION LEVELS.

Sensation Level

PERCENT TIME COMPRESSION	8	16	24	32	40	$\bar{x}$ Total
0%	71.33+	83.17	89	90.67	92.0	85.23
	63.4++	82.6	91.9	96.4	98.1	86.48
$\bar{x}$ Diff.	7.93	0.57	-2.9	-5.73	-6.1	-1.25
30%	68.0	76.67	87.67	87.17	88.5	81.6
	64.5	86.1	92.4	96.6	97.4	87.4
$\bar{x}$ Diff.	-3.5	-9.43	-4.73	-9.43	-8.9	-5.8
40%	54.33	61.16	76.17	82.5	85.33	71.99
	52.3	79.1	88.6	94	97.1	82.22
$\bar{x}$ Diff.	2.03	-17.94	-12.43	-11.5	-11.27	-10.23
50%	41.83	58.0	73.5	81.67	81.33	67.26
	49.1	71.7	85.6	92.3	95.5	78.84
$\bar{x}$ Diff.	-7.27	-13.7	-12.1	-10.63	-14.17	-11.58
60%	27.17	39.34	58.83	63.67	66.33	51.06
	47.8	70.3	83.6	90.4	94.1	77.24
$\bar{x}$ Diff.	-20.63	-30.96	-24.77	-26.73	-27.77	-26.18
70%	12.0	18.33	31.50	34.33	37.33	26.69
	15.7	32.4	50.1	65.5	80.4	48.82
$\bar{x}$ Diff.	-3.7	-14.07	-18.6	-31.17	-43.07	-22.13

+Indo-Dravidian group
++Native English group

Mean difference with a negative sign indicates higher scores by the native speakers of English.

TABLE 5. MEAN DISCRIMINATION SCORES FOR THE NATIVE SPEAKERS OF SPANISH AND ENGLISH FOR EACH CONDITION OF TIME-COMPRESSION AT FIVE SENSATION LEVELS.

Sensation Level

PERCENT TIME COMPRESSION	8	16	24	32	40	$\bar{x}$ Total
0%	65.67+	78.5	86.33	88.33	93.17	82.4
	63.4++	82.6	91.9	96.4	98.1	86.48
$\bar{x}$ Diff.	2.27	-4.1	-5.57	-8.07	-4.93	-4.08
30%	68.67	83	90.5	92.17	92.00	85.26
	64.5	86.1	92.4	96.6	97.4	87.4
$\bar{x}$ Diff.	4.17	-3.1	-1.9	-4.43	-5.4	-2.14
40%	46.17	63.33	81.67	86.00	89.67	73.36
	52.3	79.1	88.6	94	97.1	82.22
$\bar{x}$ Diff.	6.13	-15.77	-6.93	-8	-7.43	-8.86
50%	39.83	58.17	73.33	86.5	86.5	68.86
	49.1	71.7	85.6	92.3	95.5	78.84
$\bar{x}$ Diff.	-9.27	-13.53	-12.27	-5.8	-9	-9.98
60%	30.83	49.67	70.83	77.83	83.83	62.59
	47.8	70.3	83.6	90.4	94.1	77.24
$\bar{x}$ Diff.	-16.97	-20.63	-12.77	-12.57	-10.27	-14.65
70%	19.0	31.83	52.33	57.83	61.17	44.43
	15.7	32.4	50.1	65.5	80.4	48.82
$\bar{x}$ Diff.	3.3	-0.57	2.23	-7.67	-19.23	-4.39

+Spanish group
++Native English group

Mean difference with a negative sign indicates higher scores by the native speakers of English.

compression levels studied. This finding is in agreement with previous research on the discrimination abilities of native and non-native speakers (Sapon and Carrol, 1957; Politzer and McMahon, 1970; Goto, 1971; Miyawaki et al., 1973).

Effects of Time Compression on Discrimination

The results of the present study show that there is a gradual decline in the discrimination scores with increasing compression levels. This finding is in agreement with previous research employing CNC monosyllables as stimuli (Beasley, Schwimmer and Rintelmann, 1972; Beasley, Forman and Rintelmann, 1972).

The adverse effect of time compression on intelligibility may be explained in several ways. First, when the sampling technique is employed to time compress the speech stimuli, it is likely that the durational characteristics of the stimuli are affected. Householder (1971) pointed out that features of duration provided important clues in the perception of speech sounds. At the segmental level, manipulation of the durational characteristics brings about a perceptual change. Cohen, Schouten and 't Hart (1961) demonstrated that if sufficiently shortened by means of an electronic gating circuit, the segment /f/ may be perceived as /p/ or even as /b/. At the lexical level, perceptual change may be brought about by not only changing the durational characteristics of the segments, but also by manipulating the intersegmental duration. Further, perceptual changes in segments may be brought about by changing the durational characteristics of the adjacent segments. For instance, Denes (1955) found that the perception of the feature of voice could be changed by altering the durational characteristics of the adjacent vowel.

Second, with time compression, it is possible that sufficient time is not available for processing the verbal input. McNeill and Repp (1973) postulated that the duration required for processing the incoming signal might be longer than the signal. Therefore, for a significant fraction of the time, speech perception may take place in the absence of the signal. It may be suggested that with time compression, the time required for processing the information is not available to the listener.

Time compression is not always detrimental to perception. At 30% time compression, the Spanish speakers performed better than they did at 0% time compression. Similar findings have been reported with native speakers in previous research (Zemlin, Daniloff and Shriner, 1968; Beasley, Schwimmer and Rintelmann, 1972). It may be hypothesized that time compression of a small degree facilitates perception by raising the level of attention. Slow rates of speech are not necessarily conducive to maximum comprehension (Miron and Brown, 1971).

Unlike the Spanish group, the Indo-Dravidian group did not derive any benefits from 30% time compression of the stimuli. Further, pronounced differences between the two experimental groups occurred at the 60% and 70% compression levels. The dissimilarities between the Spanish and the Indo-Dravidian speakers may be attributed to the fact that the two groups of subjects acquired English in non-identical cultural settings.

In comparing the mean scores of the native and the non-native speakers, presented in Tables 4 and 5, it may be observed that the native speakers scored higher at all compression levels except at the 70% level. At this level, the Spanish speakers' scores are almost as good as those of the native speakers. However, at 40 dB sensation level the scores of the Spanish speakers are lower than those of the native speakers. This may partly be due to the fact that the data being compared are from separate studies with slightly varying experimental conditions. The mean scores of the Indo-Dravidian group are significantly lower than those of the native speakers at all compression levels. The difference between the two groups is pronounced at the 70% compression level. This indicates that non-native speakers whose native language is less similar to English experience greater difficulty in perceiving time-compressed English monosyllabic words than those non-native speakers whose native language is more similar to English.

Although differences are evident in the performance of native and non-native speakers, it should be pointed out that both groups were adversely affected by increasing levels of time compression. This demonstrates that for both native and non-native speakers, signal redundancy is reduced through manipulation of temporal characteristics.

Effect of Sensation Level on Discrimination

A significant increase in the discrimination scores was observed as a function of the sensation level. The slope of the articulation function computed between 8 and 16 dB sensation level for all levels of compression, ranges between 0.8 and 2% for the Indo-Dravidian group and between 1.6 and 2.35% for the Spanish group. These values are lower than the range, 2 and 3.5% reported for native speakers who were presented with similar stimuli (Beasley, Schwimmer and Rintelmann, 1972). This suggests that the rate of increase in the discrimination scores is slower for the non-native speakers, implying that in comparison to the native speakers, the non-native speakers seem to benefit less from increasing the signal intensity. This was especially true for 32 and 40 dB sensation levels. This implies that the native speakers were able to make use of the clues available to a greater extent than were the non-native speakers. This appears to be a reasonable explanation in view of the fact that each language differs in the number and type of speech sounds utilized for communication. Further, phonotactic rules impose restrictions on the sound sequences that are permissible in a given language. Thus, it appears that for the native speaker a certain amount of redundancy is built into his native language. In perceptual tasks, it has been demonstrated that the listeners do indeed make use of the information they have about their language (Warren and Warren, 1970; Day, 1970).

In addition to being more familiar with the sound sequences they might anticipate, it is likely that the monosyllabic words which served as the test stimuli, were more familiar to the native speakers than the non-native speakers. Several investigators have pointed out the significance of word familiarity as a variable in discrimination testing (Rosenzeig and Postman, 1957; Oyer and Doudna, 1960; Owens, 1961; Schultz, 1964).

Clinical Implications

From the clinical point of view, the impact of the present study would be to emphasize the importance of employing appropriate stimuli for diagnostic purposes. Specifically, the current discrimination tests in English must be used with caution with the non-native speakers. The audiologist should be aware that scores not within normal limits clincially, may be obtained from normal hearing non-native speakers of English. Such a contingency seems less likely to arise under the 0% compression condition when the stimuli are administered at 40 dB sensation level. When the test stimuli are presented at sensation levels lower than this level, however, the audiologist should be aware of the fact that scores below normal limits obtained from a non-native speaker may or may not be related to pathological conditions of the auditory system.

Similarly, at higher compression levels, the audiologist should guard against using the norms established for the native speakers as well as against using the norms established on a linguistic group other than the one to which the subject belongs.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND SUGGESTIONS

The effect of time-compressed speech stimuli on the discrimination ability of two groups of non-native speakers of English was examined at five sensation levels. Seventy-two normal hearing young adults in each of the groups, the Spanish speaking Mexican-American and the Indo-Dravidian, were tested using the time compressed CNC monosyllablic words from the N.U. Auditory Test No. 6, Form B, lists one through four. Each subject was required to pass a pure-tone screening test and achieve a criterion score on two English Proficiency Tests--the Michigan Test for Aural Comprehension and the Michigan Test for English Language Proficiency. The subjects were randomly assigned to one of the six compression conditions--0, 30, 40, 50, 60 and 70% compression and the lists of words were presented at 8, 16, 24, 32 and 40 dB sensation levels in a random order. The written responses were hand scored and converted into percentages.

The data were analyzed both descriptively and inferentially. The results showed a significant effect of compression levels on the discrimination scores. The two groups of subjects were affected differentially by time compression, with the Spanish speakers performing better than the Indo-Dravidian at higher levels of compression and the Indo-Dravidian subjects performing better than the Spanish only at the 0% compression level. Further, increasing the sensation level was found related to higher scores. However, an interaction effect between sensation level and time compression indicated that the effect of sensation level was not uniform at all levels of compression. Similarly, an interaction effect between sensation level and language indicated that the two groups did not benefit equally from increasing sensation levels.

The mean discrimination scores of the non-native speakers were compared with those of the native speakers from previous studies (Beasley, Schwimmer and Rintelmann, 1972; Beasley, Forman and Rintelmann, 1972). The mean scores for the non-native speakers were found to be lower than those for the native speakers at all compression levels. Further, the articulation function indicated that the non-native speakers seemed to derive less benefit from increasing sensation levels as compared to the native speakers.

Conclusions

The following conclusions seem warranted:

1. Non-native speakers of English show significant differences in the perception of time-compressed CNC monosyllabic words in English. Of the two groups studied, the native speakers of Spanish performed significantly better than the Indo-Dravidian speakers.

A comparison between native and non-native speakers indicated that the scores of both groups of non-native speakers were lower than those of the native speakers. Time compression, however, had an adverse effect on the performance of native as well as the non-native speakers.

2. Increasing levels of time compression has a detrimental effect on the perception of monosyllabic words. The magnitude of this effect is not constant for the Spanish and the Indo-Dravidian speakers. The higher compression levels had a greater detrimental effect on the Indo-Dravidian group than on the Spanish group.

3. With increasing sensation levels, there is an improvement in the perception of time-compressed speech. The magnitude of the improvements is not constant, either at various levels of compression or across the Spanish and the Indo-Dravidian groups.

Suggestions for Future Research

In the present study, a significant effect was exerted by the language groups upon the discrimination scores. To rule out the plausible explanation that the differences might have been due to the differences in the cultural setting in which English was acquired. the present study should be replicated with Spanish speakers from a foreign country.

In addition to the influence of the native language on the second language, at the phonological, lexical and syntactic levels, linguists have been interested in studying the influence of the second language on the native language. Whether such a retroactive effect might affect auditory discrimination in the first language might constitute a worthwhile study.

The present study might be extended to include other linguistic groups so as to compare significant differences in perception of time compressed stimuli, if any, among the native speakers of languages both within and between the major language families.

The present study should be replicated to determine if the differences observed between the language groups would also be found for subjects with hearing impairment.

There are few systematic studies on the auditory discrimination abilities of the bilingual children. The studies so far reported have employed non-meaningful stimuli or used a biased sample such as children from low socio-economic areas. It would seem that a study designed to compare auditory discrimination abilities of native and non-native speakers among children would not only have implications for audiological evaluations, but would also have pedagogical significance.

Perceptual errors among native and non-native speakers may be analyzed to compare the confusion mattrices of the two groups.

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APPENDICES

APPENDIX A

AMBIENT NOISE LEVELS IN TEST ROOM

TABLE A1.--Octave band and C-scale measurement of ambient noise levels in the examination room in dB SPL according to the standards specified by the American Standard Association (ASA S3.1-1960).

Test Room = IAC 1200-ACT
Microphone = B&K 4145

Sound Level Meter = B&K 2203
Octave Band Filter = B&K 1613

Center Frequency in Hertz

	C-Scale	31.5	63	125	250	500	1000	2000	4000
dB SPL*	45	43	27	15	10	<10	<10	<10	<10

*re 0.0002 dynes/cm^2

APPENDIX B

CALIBRATION PROCEDURES

The air-conduction system of the pure-tone audiometer was checked according to the procedure outlined below:
The TDH-39 earphones of the pure tone audiometer was coupled to the condenser microphone (Bruel and Kjaer, Type 4144) of the sound level meter (Bruel and Kjaer, Type 2203) with its associated octave band filter network (Bruel and Kjaer, Type 1613) by means of a standard 6-cc coupler. The output of each earphone was checked at octave intervals from 250 through 8000 Hz. In addition, the linearity of the attenuator was checked with a 1000 Hz input signal. The output as well as the attenuator linearity was found consistent with American National Standards Institute (ANSI) 1969 "Specifications for Audiometers."

The speech audiometer was calibrated using the same calibrating equipment described above. It was calibrated such that audiometric zero was defined as being 20 dB above 0.0002 dynes/cm^2. The procedure, utilizing speech spectrum noise as recommended by Tillman, Johnson and Olson (1966) was as follows: The level of the noise signal at a given attenuator setting was adjusted until it produced a deflection to 0 dB on the vu meter. The resultant acoustic output of the system was accepted as the intensity of the words at the same attenuator setting at which the peaks of the words produced a deflection to zero on the vu meter of the speech audiometer. For example, with the speech audiometer set at 60 dB, the output of the artificial ear would be 80 dB SPL re: 0.0002 $dynes/cm^2$.

Linearity of the attenuator on the speech audiometer was checked as follows: A 1000 Hz tone was channeled into the sound level meter assembly at maximum attenuator setting and the resultant sound pressure level was noted. The intensity of the tone was then attenuated successively in 10 dB steps and a corresponding decrease in the output was anticipated. No deviations from the anticipated readings were observed.

To test harmonic distortion, the output of the earphone was led to the amplifer input of the frequency analyzer (Bruel and Kjaer, Type 2107). The distortion factor was then measured directly by switching the analyzer to 'frequency rejection'. Thus, the fundamental was rejected and the remaining total harmonic distortion was read directly in percent from the instrument meter with the switch set in the RMS position. The harmonic distortion of the speech audiometer was within the limits specified by ANSI (1969).

A graphic record of the frequency response characteristics of the earphones was obtained prior to and following experimentation. The instrumentation employed was as follows: A sine random generator (Bruel and Kjaer, Type 1024) was connected to the 6-cc coupler (Bruel and Kjaer, Type 4152) which was in turn connected to the amplifier portion of the audio frequency spectrometer (Bruel and Kjaer, Type 2112). The amplified voltage was led to the input of the level recorder (Bruel and Kjaer, Type 2305) which automatically recorded the frequency response of the earphone. No changes were observed in the earphone characteristics between the pre- and post-experiment measurements.

Prior to each experimental session, the output SPL of the speech audiometer was measured. The linearity of the attenuator was checked periodically. Also the output of the pure tone audiometer and its attenuator were checked periodically. No changes from the prescribed values (ANSI 1969) were observed during experimentation.

APPENDIX B

TABLE A2.--Pre- and post-experimental linearity check of the Grason-Stadler Speech audiometer attenuator made acoustically at the earphone.

Audiometer = Grason-Stadler Model 162
Audiometer Channel = Grey
Earphone = Left (TDH-39/10Z)
Earphone Cushion = MX-41/AR

Artificial Ear = B&K 4152
Sound Level Meter = B&K 2203
Microphone = B&K 4144
Octave Band Filter = B&K 1613

	Pre-Experiment 1000 Hz		Post-Experiment 1000 Hz	
dB HTL	dB SPL	dB diff	dB SPL	dB diff
100	117		117.5	
90	108.5	9.5	108	9.5
80	99	9.5	98	10
70	89	10	88	10
60	79	10	78	10
50	69	10	68.5	9.5
40	59	10	58	10.5
30	49.5	10.5	48	10
20	39.5	10	38.5	9.5

APPENDIX B

EARPHONE FREQUENCY RESPONSE

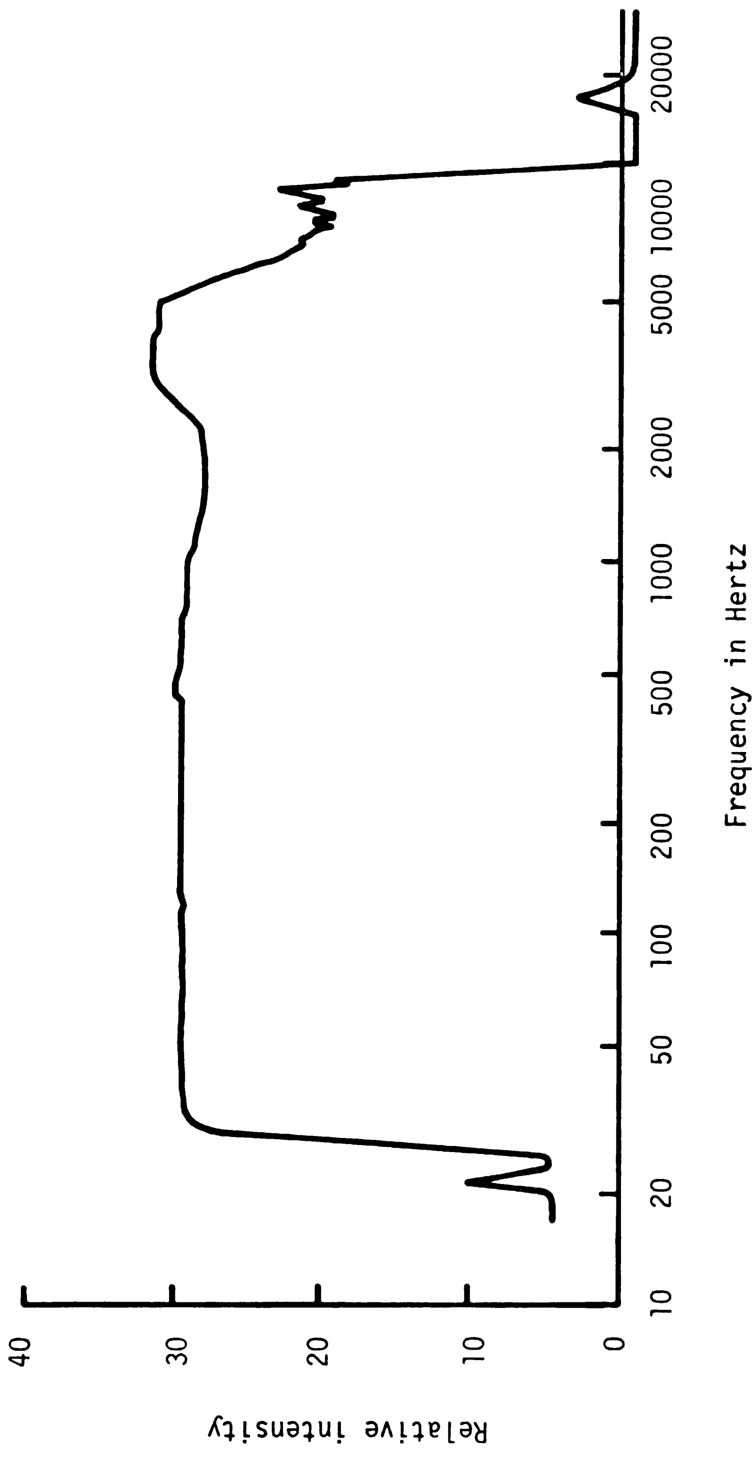

Figure A1.--Frequency response of test earphone.

APPENDIX C

CONVERSION FORMULA FOR ENGLISH TEST

Number of Mistakes	Grade
0	100
1	99
2	98
3	98
4	97
5	96
6	95
7	94
8	93
9	92
10	91
11	90
12	89
13	88
14	87
15	86
16	85
17	84
18	83
19	82
20	81
21	80
22	79
23	77
24	76
25	75

INDIVIDUAL DATA FOR THE INDO-DRAVIDIAN SPEAKERS

TIME COMPRESSION: 0%							TIME COMPRESSION: 30%						
	Sensation Level					$\bar{x}$		Sensation Level					$\bar{x}$
Subject	8	16	24	32	40	Total	Subject	8	16	24	32	40	Total
1	82	92	94	96	98	92.4	1	64	58	90	94	92	79.6
2	78	68	90	82	94	82.4	2	94	94	94	98	96	95.2
3	78	78	86	96	92	86	3	76	82	98	92	98	89.2
4	94	94	96	96	94	94.8	4	90	96	92	96	88	92.4
5	88	88	96	98	96	93.2	5	80	84	84	88	96	86.4
6	76	78	84	84	84	81.2	6	76	86	90	74	90	83.2
7	86	90	80	92	94	88.4	7	28	50	60	72	72	56.4
8	64	92	92	90	86	84.8	8	62	72	78	82	72	73.2
9	50	72	88	82	82	74.8	9	78	90	98	92	90	89.6
10	54	84	80	83	96	80.4	10	68	66	82	68	88	74.4
11	62	80	90	92	96	84	11	16	46	90	92	82	65.2
12	44	82	92	92	92	80.4	12	84	96	96	98	98	94.4

INDIVIDUAL DATA FOR THE INDO-DRAVIDIAN SPEAKERS

TIME COMPRESSION: 40% TIME COMPRESSION: 50%

	Sensation Level					$\bar{x}$		Sensation Level					$\bar{x}$
Subject	8	16	24	32	40	Total	Subject	8	16	24	32	40	Total
1	78	84	86	96	86	86.0	1	20	50	74	72	72	57.6
2	76	56	54	62	82	66.0	2	80	62	86	72	88	77.6
3	62	46	74	76	78	67.2	3	68	64	84	90	90	79.2
4	94	74	88	96	94	89.2	4	48	60	80	92	84	72.8
5	20	58	72	88	78	63.2	5	60	78	88	80	92	79.6
6	56	50	74	82	88	70.0	6	56	64	78	86	84	73.6
7	50	68	78	92	88	75.2	7	54	68	68	84	74	69.6
8	78	78	86	96	92	86.0	8	18	38	36	60	56	41.6
9	32	52	80	74	80	63.6	9	32	62	80	90	84	69.6
10	46	60	84	68	88	69.2	10	20	56	76	90	90	66.4
11	22	52	56	74	84	57.6	11	34	52	68	86	82	64.4
12	38	56	82	86	92	70.8	12	12	42	64	78	80	55.2

INDIVIDUAL DATA FOR INDO-DRAVIDIAN SPEAKERS

TIME COMPRESSION: 60%							TIME COMPRESSION: 70%						
	Sensation Level					$\bar{x}$		Sensation Level					$\bar{x}$
Subject	8	16	24	32	40	Total	Subject	8	16	24	32	40	Total
1	26	38	70	70	70	54.8	1	16	16	26	30	26	22.8
2	28	54	76	72	80	62	2	74	60	80	78	90	76.4
3	36	36	60	62	56	50	3	8	14	48	42	58	34
4	20	32	60	64	72	49.6	4	0	2	8	18	6	6.8
5	30	44	46	66	68	50.8	5	8	36	34	48	64	38
6	48	48	58	58	74	57.2	6	4	4	10	12	6	7.2
7	34	22	54	60	62	46.4	7	18	30	40	26	42	31.2
8	34	36	56	66	60	50.4	8	10	20	20	30	26	21.2
9	20	44	64	60	72	52	9	0	4	26	26	12	13.6
10	4	50	62	64	74	50.8	10	6	20	42	52	70	38
11	42	50	66	78	76	62.4	11	0	0	16	24	20	12
12	4	18	34	44	32	26.4	12	0	14	28	26	28	19.2

INDIVIDUAL DATA FOR SPANISH SPEAKERS

TIME COMPRESSION: 0%							TIME COMPRESSION: 30%						
	Sensation Level							Sensation Level					
Subject	8	16	24	32	40	$\bar{x}$ Total	Subject	8	16	24	32	40	$\bar{x}$ Total
1	76	94	90	94	98	90.4	1	80	92	96	96	98	92.4
2	96	90	92	96	98	94.4	2	78	86	90	90	94	82.6
3	72	82	94	90	98	87.2	3	96	92	98	94	98	95.6
4	72	90	96	98	96	90.4	4	84	80	94	92	90	88
5	70	88	96	90	96	88	5	82	86	94	92	98	90.4
6	70	62	66	68	80	69.2	6	68	82	88	98	90	85.2
7	68	66	84	88	90	79.2	7	78	82	98	96	90	88.8
8	54	70	84	82	90	76	8	84	94	86	88	90	88.4
9	46	74	88	88	86	76.4	9	70	92	98	94	92	89.2
10	56	68	70	80	94	73.6	10	24	60	84	88	98	70.8
11	64	88	92	96	96	87.2	11	40	72	80	90	80	72.4
12	44	70	84	90	96	76.8	12	40	78	80	88	86	74.4

INDIVIDUAL DATA FOR SPANISH SPEAKERS

TIME COMPRESSION: 40% | TIME COMPRESSION: 50%

	Sensation Level					$\bar{x}$		Sensation Level					$\bar{x}$
Subject	8	16	24	32	40	Total	Subject	8	16	24	32	40	Total
1	64	78	90	90	92	82.8	1	40	72	88	94	92	77.2
2	72	84	82	96	92	85.2	2	68	68	80	96	84	79.2
3	28	50	88	86	98	70	3	38	70	82	84	94	73.6
4	34	60	70	86	88	67.6	4	40	40	62	86	72	60
5	38	66	78	86	88	71.2	5	20	56	74	92	88	66
6	78	74	92	90	96	86	6	52	60	76	86	90	72.8
7	32	46	76	94	94	68.4	7	48	78	78	90	86	76
8	58	80	96	94	90	83.6	8	52	48	70	82	96	69.6
9	42	48	78	76	82	65.2	9	32	52	74	88	78	64.8
10	56	78	92	80	90	79.2	10	22	42	54	74	86	55.6
11	16	56	70	80	86	61.6	11	54	72	80	92	94	78.4
12	36	40	63	74	80	59.6	12	12	40	62	74	78	53.2

INDIVIDUAL DATA FOR SPANISH SPEAKERS

	TIME COMPRESSION: 60%							TIME COMPRESSION: 70%					
	Sensation Level							Sensation Level					
Subject	8	16	24	32	40	$\bar{x}$ Total	Subject	8	16	24	32	40	$\bar{x}$ Total
1	38	58	88	88	96	73.60	1	0	10	42	60	56	33.6
2	44	64	76	88	88	72.00	2	24	30	56	62	68	48.0
3	28	42	62	68	76	55.20	3	32	38	72	62	60	52.8
4	60	80	80	90	80	78.00	4	12	52	68	46	64	48.4
5	16	48	60	80	90	58.80	5	18	30	44	56	62	42.0
6	40	56	72	80	90	67.60	6	20	20	40	46	60	37.2
7	46	62	88	82	86	72.80	7	38	42	40	74	68	52.4
8	28	40	64	64	80	55.20	8	10	30	44	50	40	34.8
9	4	14	70	70	82	48.0	9	36	46	72	70	72	59.2
10	0	22	40	54	70	37.20	10	22	24	40	52	74	42.4
11	42	62	80	92	94	74.0	11	16	42	66	76	70	54.0
12	24	48	70	78	74	58.8	12	0	18	44	40	40	28.4