TIME COMPRESSED SPEECH TEST IN ENGLISH FOR CHILDREN: 7- 12 YEARS

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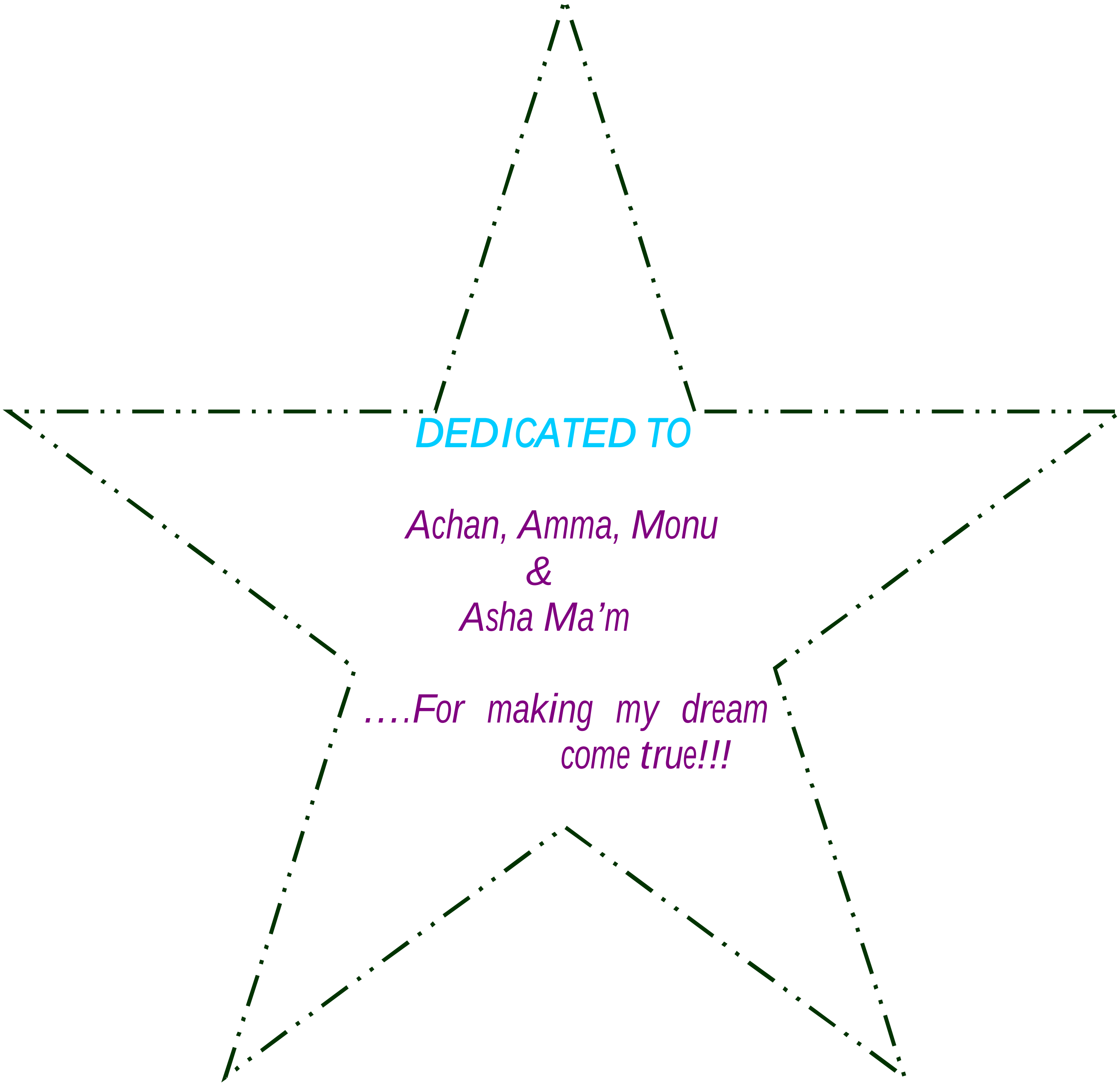

DEDICATED TO

Achan, Amma, Monu
&
Asha Ma'm

….For making my dream
come true!!!

CERTIFICATE

This is to certify that this dissertation entitled **"TIME COMPRESSED SPEECH TEST IN ENGLISH FOR CHILDREN: 7-12 YEARS"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **"TIME COMPRESSED SPEECH TEST IN ENGLISH FOR CHILDREN: 7-12 YEARS"** is the bonafide work in part fulfillment for the degree of Master of Science (Audiology) of the student with **Reg. No. AO390015.** This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This dissertation entitled **"TIME COMPRESSED SPEECH TEST IN ENGLISH FOR CHILDREN: 7-12 YEARS",** is the result of my own study under the guidance of **Dr.Asha Yathiraj,** Reader and HOD, Dept of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any university for any other Diploma or Degree.

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CONTENTS

Page number

1. List of tables
2. List of figures
3. Introduction 1
4. Review of literature 7
5. Method 47
6. Results and discussion 52
7. Summary and conclusions 68
8. References 72

List of tables

Sl No.	Title	Page no.
Table1	Mean and standard deviation for right and left ears, males and females across age groups for different levels of compression.	53
Table 2	F values, degrees of freedom and significance of difference for different compression levels across age	57
Table 3	Level of significance between age groups, across compression levels	59
Table 4	Degrees of freedom, F values and significance of difference of means for different compressions within age groups	62
Table 5	Mean, SD, Confidence Interval, Minimum and Maximum scores for all age groups at different levels of compression	63

List of figures

Sl No.	Title	Page no.
Figure 1	Error graph for 7-7.11 years	64
Figure 2	Error graph for 8-8.11 years	64
Figure 3	Error graph for 9-9.11 years	64
Figure 4	Error graph for 10-10.11 years	64
Figure 5	Error graph for 11-11.11 years	64

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Hold on tight and don't let go!!!!!!!!
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INTRODUCTION

"Music is perpetual,
And only the hearing is intermittent"
- Henry David Thoreau

Hearing is a complex process that is often taken for granted. As sounds strike the eardrum, the sounds (acoustic signals) begin to undergo a series of transformations through which the acoustic signals are then passed from the ear through complicated neural networks to various parts of the brain for additional analysis, and ultimately, recognition or comprehension. Central auditory processing (CAP) is the label ascribed to this neurologic phenomenon. This term is used interchangeably with other terminology such as central auditory ability, central auditory perception and central auditory function (Hull & Dilka, 1984).

Some individuals may have an Auditory Processing Disorder (APD) thus having difficulty in processing auditory information when presented in a less than optimal listening environment. They have no trouble detecting the presence of sound, but have other types of auditory difficulties (e.g. difficulties understanding conversations in noisy environments, problems following complex directions, difficulty learning new vocabulary words or foreign languages) that can affect their ability to develop normal language skills, succeed academically, or communicate effectively (Mueller and Bright, 1994).

For the successive treatment of this condition proper assessment is necessary. The purpose of the central auditory processing evaluation is to help define the specific auditory processing difficulties that a child may be experiencing and to recommend appropriate remediation (Wertz, Hall, and Davis, 2002).

The assessment of central auditory processing must thus begins with careful observation of the child, with particular attention to the auditory behaviour patterns. When possible, an in-depth history from the child's parent or guardians should be taken. Hearing evaluation to rule out peripheral hearing loss is also essential.

Willeford and Burleigh (1985) suggested two very different approaches to test central auditory abilities. The first approach used primarily by speech language and reading and learning disability teachers involves assessing auditory abilities, assumed by them to be prerequisites to language acquisition or reading skills. The tests assess the auditory attention, auditory figure-ground, auditory discrimination, auditory memory etc. A second and very different approach to assess auditory perceptual abilities is used by audiologists. This approach evaluates the child's ability to respond under different conditions of signal distortion and competition. The principle of the approach assumes that a normal listener can tolerate mild distortions of speech and still understands it. A listener with an auditory processing deficit will encounter difficulties with the distorted stimulus due to added internal distortion. Auditory tests used in accessing development integrity or maturation of the auditory nervous system include Masking Level Difference (MLD), (Hirsh, 1948, cited in Schoeny, & Talbott, 1994), staggered spondaic words (SSW), (Katz, 1962, cited in Schoeny, & Talbott, 1994), Consonant-vowel Identification Test, (Berlin, 1973, cited in Schoeny, & Talbott, 1994) and many others.

Temporal features of the acoustic signal play an important role in speech perception. Hence, the use of distortion in the time domain of speech has considerable potential as a measure for assessing central auditory nervous system disorders. Time compressed speech tests have been developed using both monosyllables (Beasley, Schwimmer & Rintelmann, 1972a) and sentences (Beasley & Shriner, 1973). Findings in subjects with neurological dysfunction indicate that time compressed speech tasks are most sensitive to diffuse pathology involving the primary auditory cortex, particularly at the higher degrees of compression (Kurdziel, Noffsinger & Olson, 1976; Baran, Verkest, Gallegly, Kibbe-Michal & Rintelmann, 1985; Meuller, Beck, & Sedge, 1987). As the compressed speech task has a temporal element in its design it may also provide insight into a temporal processing problem.

Research with peadiatric tests of central auditory function accelerated in the 1980s. Several tests have been developed for children to help identify whether the auditory system is functioning normally (Keith & Jerger, 1990, cited in Jacobson and Norther, 1990). These tests provide information on whether there is a neurologic basis for a language learning disorder as shown by reserved cerebral dominance, depressed overall performance, immature auditory receptive abilities or failure of interhemispheric transfer of information. More commonly, central auditory testing in children is used to determine the functional auditory ability. They describe a child’s ability to process speech under various difficult listening conditions.

Need for the Study:

The Speech-In–Noise Test is the only monaural low redundancy speech test available at present for Indian population. Although speech-in-noise tests have been shown to be atleast marginally sensitive to a wide variety of disorders of the central auditory nervous system and related disorders (Dayal, Tarantino, & Swisher, 1996; Chermak, Vonhof, & Bendel, 1989), lack of standardized test tools and material-specific normative data have resulted in conflicting findings and questionable test reliability. Therefore, Mueller and Bright (1994) have suggested that speech-in-noise tests may well be the most misused test of central auditory function. Hence, there is a need to develop another monaural speech test.

In literature, there are many studies demonstrating that children with Learning Disability (LD) may have auditory and/or visual processing problems (Larsen, Rogers, & Sowell, 1976; Kraus & McGee, 1994). Hence there need to be tests to detect their problems. In India it has been found that the percentage of children to have dyslexia ranges from 3% (Ramaa, 1985) to 7.5% (Nishi Mary, 1988, cited in Ramaa, 2000). Most often than not these children go unidentified and drop out of school because of poor academic performance. Tests developed in the west cannot be directly used in India due to variation in accent and vocabulary used. Hence, there is a need to develop a test appropriate for Indian context.

The tests of central auditory dysfunction must be carefully interpreted according to normative data. The time compressed speech test, is one such test used for central auditory dysfunction evaluation. Norms for this test has been reported by Beasley et al.

(1972a) and Beasley, Forman and Rintelmann (1972b) for the Western population. No such study has been developed for the Indian population. Therefore, the present study has been taken up to establish normative data in Indian children. This will help in the diagnosis of children with auditory perceptual problems, whose scores on the time compressed test can be compared with the norms available.

Studies using time compressed version of the NU-6 word lists (30-70% compression at 40 dBSL) indicate that normal listeners demonstrate a reduction in word recognition scores as the degree of compression increases, culminating in a marked deterioration in performance with 70% compression (Beasley et al., 1972a; Beasley et al., 1972b).Thus, the most commonly used compression rate has been 60% so that the peculiar vocal distortions that accompany standard speech recordings when they are played back at rates faster than those at which they were recorded are avoided (Willeford & Burleigh, 1985). The present study also aims to verify if perception of time compressed speech deteriorates as the degree of compression increases, in the Indian children.

The average intelligibility scores as measured by time compressed monosyllables, has been found to increase systematically as a function of age in normal children (Beasley, Maki & Orchik, 1976; Nagafuchi, 1976). There was no significant difference found between boys and girls in terms of their average intelligibility scores (Nagafuchi, 1976). This reflects the maturation of the central auditory processing mechanism. The present study, thus, focuses on any systematic increase in auditory capacity in the group of normal children as a function of age.

Aim of the study:

The present study had the following aims:

- Developing Time Compressed Speech Test in English, for non native speakers of English. The test will have different compression levels.
- Investigating if there is any ear effect on the scores of time compressed words.
- Investigating if the scores are different across gender.
- Investigating if level of compression affects the scores obtained.
- Developing norms for different age groups across different levels of compression (age effect).

There are several variables that can affect the results of time compressed speech. It is important that the influence of these variables be noted prior to the development of a time-compressed speech test. In the following chapter a detailed review is provided regarding the factors that influence time-compressed speech tests.

REVIEW OF LITERATURE

Central auditory processes are the auditory system mechanisms and processes responsible for several behavioural phenomena which include: Sound localization and lateralization; auditory discrimination; temporal aspects of audition including; temporal resolution, temporal masking, temporal integration and temporal ordering; auditory performance with competing acoustic signals and auditory performance with degraded signals. These mechanisms and processes apply to nonverbal as well as verbal signals and may affect many areas of function, including speech and language. A central Auditory Processing Disorder (CAPD) can be defined as a deficiency in any one or more of the behavioural phenomena listed above (ASHA Task Force, 1996).

An exponential growth in knowledge and technology has placed significant stress on each child's sensory and learning abilities. The child now needs to listen for long periods in noisy, large classrooms, remember more complex information at an earlier age and memorize not only for short durations but for long durations. As a result, reports of children with central auditory processing problems have also increased exponentially. There is a need to diagnose these conditions.

Diagnosis of Auditory Processing Disorders:

Diagnosis of APD is essential for the implementation of appropriate therapeutic and/or remedial strategies. Formal diagnosis is accomplished through administration of a battery of tests, each designed to stress various behavioural processes required to process auditory information. Although general information can be obtained as early as 5 ½ - 6 ½ years of age, the administration of the comprehensive central auditory pathway test battery is not performed until the age of 6 ½- 7 years or later to minimize any bias introduced by limited vocabulary and/or attention. In younger children, informal diagnosis is made utilizing behavioural information in conjunction with speech language measures (Willeford & Burleigh, 1985; Bellis, 1996).

The audiologist assesses the peripheral and central auditory systems using a battery of tests, which may include both electrophysiological and behavioural tests. Peripheral hearing tests determine if the child has a hearing loss and if so, the degree to which the loss is a factor in the child’s learning problems. Assessment of the central auditory system evaluates the child’s ability to respond under different conditions of auditory signal distortion and competition. It is based on the assumption that a child with an intact auditory system can tolerate mild distortions of speech and still understand it, while a child with APD will encounter difficulty when the auditory system is stressed by signal distortion and competing messages (Keith, 1995). The test results allow the audiologist to identify strengths and weaknesses in the child’s auditory system that can be used to develop educational and remedial intervention strategies.

The behavioural tests are often broken down into four sub-categories, including monaural low redundancy speech tests, dichotic speech tests, temporal pattering tests, and binaural interaction tests. It should be noted that children being assessed for APD would not necessarily be given a test from each of these categories. Rather, the audiologist will select a battery of tests for each child. The selection of tests will depend upon a number of factors, including the age of the child, the specific auditory difficulties the child displays, the child’s native language and cognitive status, and so forth (Willeford & Burleigh, 1985).

In the following section a detailed review of a monaural low redundancy test is given. Due to the richness of the neural pathways in our auditory system and the redundancy of acoustic information in spoken language, a normal listener is able to recognize speech even when parts of the signal are missing. However, this ability is often compromised in the individual with APD. Monaural low redundancy speech tests represent a group of tests. These tests include Low pass filtered speech (Bocca, Calearo & Cassinari, 1954, cited in Mueller & Bright, 1994), Speech-in-noise test, the Synthetic Sentence Identification test with Ipsilateral Competing Message (Jerger & Jerger, 1974) designed to test an individual’s ability to achieve auditory closure when information is missing. The speech stimuli used in these tests have been modified by changing one or more of the following characteristics of the speech signal: frequency, temporal or intensity characteristics. Time compressed speech is one such test, originally designed by Beasley et al., 1972a, b to evaluate monaural low redundancy.

Time Compressed Speech as a Measure of APD-

History in the development of time compressed speech:

One way to reduce the redundancy of a speech signal is to alter the temporal characteristics of the signal. Speech can be temporally altered in a variety of ways. The speaker can simply talk faster, or recorded material can be played back at a higher speed.

Early interest in the study of time-altered speech was made possible by the development of the tape recorder. By employing the tape recorder, Fletcher, 1929 (cited in Beasley & Freeman, 1977) was able to record a message and subsequently play back the message at a faster or slower speed than was originally recorded. This “Fast Playback” procedure enabled the investigator to retain central of certain proportional relationships inherent in the original signal. This procedure resulted in undesirable shifts in the frequency characteristics of the recorded signal.

In order to overcome the problem of the frequency shifts associated with the fast/slow playback technique, a chop-splice procedure was employed by certain investigators, for example Garvey, 1953a, b (cited in Beasley & Freeman, 1977). In this procedure, certain segments of the recorded signal were manually cut from the recording and the retained samples were spliced back together. This method permitted the experimenter to vary the temporal nature of the signal without undue distortion of the frequency characteristics of the signal as originally recorded. In addition, the investigator was able to delete and retain selected segments of the signal and to systematically vary the temporal length of these segments. However, this procedure was proved to be cumbersome and inefficient.

Fairbanks, Everitt and Jaeger, 1954 (cited in Beasley & Freeman, 1977) developed the electromechanical time compressor/ expander. Using this device, investigators were able to record a signal and subsequently delete and retain samples of the signal automatically. Further, the retained samples were electromechanically "spliced" back together, such that the end procedure was a recorded version of the original recording, which was some specific percentage shorter (compressed) or longer (expanded) than the original. The Springer Information Rate Changer was an electromechanical device similar to the Fairbanks device except that the discarded interval had a limited range of variability. The Lee, 1972 Varispeech device, a modification of the Fairbanks instrument, contains a small tape recorder and minicomputer and was the one most widely used for time-compressed speech. A drawback of both the Fairbanks and Lee devices was that the sampling was random so samples discarded could be within as well as between linguistic sections. Currently there are several soft wares available that can compress or expand the speech signal (Beasley & Freeman, 1977).

Time–compressed speech is generally described in terms of the percentage of temporal reduction, that is, 30% time compressed speech is speech in which 30% of the signal has been removed in small units (Katz, 1994, cited in Mueller & Bright, 1977).

Development of Time Compressed Speech for Clinical Purposes:

The use of time-compressed / expanded speech as a part of the clinical test battery has grown out of the need to detect subtle neurological lesions that may go unnoticed by use of standard pure tone and word discrimination measures of audition. These implications have been based upon the subtlety and bottleneck principle exposed by Jerger (1960, cited in Beasley & Freeman, 1977). He noted that, because of the complexity and neural redundancy of the central nervous system, measures of retro cochlear auditory dysfunctions required stimuli of a complex nature. Calearo and Lazzaroni (1957, cited in Beasley & Freeman, 1977) and de Quiros (1964, cited in Beasley & Freeman, 1977) recognized this problem and consequently employed time-compressed speech signals as a measure for evaluating lesions in the central auditory nervous system. Calearo and Lazzaroni pointed out that the time compression reduced the external temporal redundancy of the normal speech signal, thereby increasing the difficulty of the processing task by the internally redundant central nervous system. However, the procedures employed by them were not well described nor were norms provided for clinical use.

Luterman, Welsh, and Melrose (1966) followed by a study by Sticht and Gray (1969) presented the CID W-22 word lists to normal hearing and sensorineural hearing impaired young and aged adult listeners. The authors of both studies concluded that their results indicated that time altered speech, as they employed it, did not effectively differentiate young and aged listeners, nor did it effectively differentiate normal listeners from persons with sensorineural hearing impairments. These conclusions were questioned by Beasley and Maki, 1976 (cited in Beasley & Freeman, 1977) based upon the fact that the stimulus material employed may have been too easy to allow for differentiation between populations to occur. Further, the presenting hearing losses were mild and thus not necessarily problem causing for the sensorineural population. The two studies also employed limited sample sizes and compression levels. Nevertheless, the studies by Lutermann et al. (1966) and Sticht and Gray (1969) provided the necessary impetus to investigators to pursue studies of the temporal nature of auditory processing for clinical purposes.

Willeford (1976a, b, cited in Beasley & Freeman, 1977)) had noted that one of the major difficulties in the plethora of development of “tests” for auditory processing problems was the lack of normative studies for purposes of determining validity and reliability Thus, prior to consideration of clinical application of time-altered speech, normative data was generated in a series of studies.

Beasley et al. (1972a) presented the Rintelmann and Jetty (1968, cited in Beasley & Freeman, 1977)) recorded version of Form B of the Northwestern University Auditory Test No. 6 (NU-6) (Tillman & Carhart, 1966, cited in Beasley & Freeman, 1977)), to 96 normal-hearing young adults at sensation levels of 8, 16, 24 and 32 dB. Using the Zemlin modification of the Fairbanks device, the four lists of Form B were time-compressed from 0% to 70% in 10% steps and presented to the listeners in an experimental design employing a counter balancing procedure. The average percentage correct responses increased as a function of increasing sensation level and decreasing percentage of time compression.

There was a dramatic drop in intelligibility at 70% time compression. The articulation functions across sensation levels ranged from 2% to 3.5% / dB, and these were similar to the articulation functions obtained by Rintelmann and Jetty, 1968 (cited in Beasley & Freeman, 1977) on the unmodified versions of the NU-6 (form B). In a subsequent study by Beasley et al. (1972b), the same stimuli were presented to a different group of normal hearing young adults at 40 dBSL. There was a slight but non-significant increase in the percent correct scores obtained at 40 dBSL compared to those obtained at 32 dBSL. Moreover, the difference appeared to increase in prominence as the listening task increased in difficulty, i.e. as the percentage of time compression increased.

There is evidence however, that the time-compressed NU6 lists, commercially available from Autidec since 1978, were significantly difficult for normal listeners than the recordings used by Beasley and Colleagues (De Chicchis, Orchik & Tecca, 1981; Grimes, Meuller & Williams, 1984).

Normative data were also obtained by De Chicchis et al. (1981) for the Auditec uncompressed recordings of the NU-6 and W-22 word lists compressed using the Varispeech II time compressor/ expander. The scores reported by De Chicchis et al. (1981) for the NU-6 word lists were significantly poorer than those reported by the Beasley et al. (1972a, b) norms. Beattie (1986) obtained normative performance-intensity functions for the Auditec CID W-22 recordings with 30% and 60% time compressed version of the NU-6 Form A tape was made commercially available by Auditec of St. Louis in 1978. Compression was obtained using the Varispeech II device.

Using the recorded version of the time compressed speech test several studies were conducted. They reported of several variables that affected the results of these tests.

Factors Affecting The Performance of Time Compressed Speech Test:

There are certain factors that can affect the performance of time compressed speech test. They are as follows:

1) Effect of level of compression

Fairbanks, Guttman and Miron (1957) developed pair of independent message test units, each consisting of an extended exposition of technical information and a corresponding test by factual comprehension. The messages were read by an experienced speaker at 141 wpm, recorded, and compressed automatically in time by various amounts. Independent groups of subjects, all Air Force trainees were assigned to five experimental conditions that represented two series of compressions ranging from 0 to 70%. The curve of comprehension as a function of message time was characteristically sigmoid. Response was approximately 50% of maximum when message time was 40% (60% compression, 353 wpm). When message time was 50% (282 wpm), the response was slightly less than 90% and efficiency, response per time, was maximal.

Zemlin, Daniloff and Shriner (1968) conducted a study in which 40 normal college students rated the difficulty of listening to samples of speech subjected to 20, 30, 40 and 50% time compression compared with a standard consisting of normal speech. Male and female speakers were used. Results indicated that difficulty commences to increase and accelerated beyond 20% time compression to reach a value of about five times as difficult at 50% time compression.

Riensche, Konkle and Beasley (1968) presented Form A of the Northwestern University Auditory Test 6 (NU-6: CVC monosyllables) to 80 normal hearing young adults at four sensation levels (8-32 dB) and five percentages of time compression (0-60%). The results for different time compression showed that performance decreased as a function of increasing time compression.

The time-altered versions of the Auditec recordings of CID W-22 and Northwestern Auditory Test No. 6 (NU-6) were compared by De Chicchis et al. (1981) at five time-compressed ratios (0%, 30%, 40%, 50% and 60%). The test was carried out on 28 normal hearing listeners. NU-6 scores were consistently poorer than the W-22's with significant differences observed at the 30% and 60% time compressed conditions. The decrease in speech intelligibility with increasing rates of time compression was consistent with previously published data. Similar results have been reported using time-altered versions of a number of speech discrimination tests (Sticht & Gray, 1969; Beasley et al., 1972a; Kurdziel, Rintelmann & Beasley, 1975; Beasley, Maki & Orchik, 1976; and Schwartz & Mikus, 1977). The decline in performance simply reflects the increased difficulty of the listening task at higher levels of time compression.

Thus, it is seen that as the level of compression is increased the performance reduces, and above 50% compression scores drop down drastically.

2) Effect of Stimulus material

Beasley et al. (1976) have presented the results of the use of time compressed speech with 6 children aged 4, 6 and 8 years. The subjects were presented two frequently used audiologic measures of children's auditory discrimination: the Word by Picture Identification (WIPI) test (Leman, Ross & Mc Laughlin, 1965), a closed response task, and the PB-K 50 of Haskins Lab., an open-response task. The results of the Beasley et al. study indicated that the closed response WIPI, a visual pointing task, generally was easier than the open response PB-K 50 when the words were time compressed by 0%, 30% and 60% of normal duration. Further, intelligibility decreased as a function of increasing time compression and decreasing age and sensation level, and these effects were particularly pronounced for the more difficult PBK-50. The authors concluded, in support of Hodgson (1973, cited in Beasley et al., 1976), that the PBK-50 could be used effectively with older children, but that the WIPI was probably more appropriate for younger children and/or children who, for whatever reason, were difficult to test.

The time-altered versions of the Auditec recordings of CID W-22 and Northwestern Auditory Test No. 6 (NU-6) were compared by De Chicchis et al. (1981) at five time-compressed ratios (0%, 30%, 40%, 50% and 60%). The test was carried out on 28 normal hearing listeners. NU-6 scores were consistently poorer than the W-22's with significant differences observed at the 30% and 60% time compressed conditions.

Foltner, Beasley and Whitem (1979) time compressed list A and B of the C.I.D W-1 spondees with a lexicon Varispeech I unit. SRTs were collected from one ear of each of 60 normal hearing young adults. No list differences were found. The right ears of 30 subjects were superior to the left ears of 30 subjects by 0.8 dB. Mean SRTs collapsed across lists and ears were 9.3, 10.7, 13.2 dB for the compressions in the order 0, 40 and 60% respectively. The differences were judged clinically insignificant, nevertheless when considered with earlier data authors concluded that time compressed spondees may come to have use as a clinical device.

Time compressed monosyllables have been studied relative to the assessment of central auditory disorders (Kurdziel, Noffsinger & Olsen, 1976, cited in Sharp, Daniel, and Orchik, 1978; Manning, Johnson, & Beasley, 1977; Snow, Rintelmann, Miller & Konkle, 1977). In certain instances, sentential stimuli may be more useful than word lists in central auditory testing, particularly when the results may be contaminated by concomitant peripheral hearing losses. Beasley, Bratt and Rintelmann (1980) presented Central Institute for the Deaf (CID) and Revised CID (RCID) sentence lists and a contrived sentential approximation task to 96 normal hearing adults at time-compression ratios of 0%, 40%, 60% and 70%, under sensation levels of 24 and 40 dB. The CID and RCID stimuli were more intelligible than the sentential approximations. The higher intelligibility of the time-compressed CID and RCID sentences, relative to the time compressed monosyllables, probably resulted from the redundant nature of the sentence stimuli. Although the CID and RCID scores were better than the NU-6 scores at all ratios of time compression, the effect of the degradation process between 60% and 70% time compression was nearly as great for the two sentence tests as it was for the NU-6 monosyllables, implying that the sentences were nearly as sensitive to the effects of time compression as the monosyllables. The authors concluded that the time compressed sentence stimuli, particularly the CID and RCID sentences, may be useful as a means for evaluating central auditory problems in patients with concomitant peripheral auditory pathologies.

Thus, monosyllabic words are found to be more sensitive than sentential stimuli. But score of 60% and 70% compressed version of both monosyllables and sentences were found to be same. So it can be concluded that sentences can be used for cases with concomitant peripheral hearing loss in order to give redundant cues. It should be noted that the variation in scores might also be due to the influence of the subjects, the recording method and the equipment used for preparing as well as presenting the material.

3) Effect of presentation level

Beasley et al. (1972a) evaluated 96 normal hearing subjects using the NU Auditory test No. 6 under six conditions of time compression (0-70%) at four sensation levels (SLs) 8-32 dB. Intelligibility decreased as time compression increased, but increasing SL offset part of this effect. Further, the curves for the several levels of time compression appeared to plateau at 32 dBSL, the highest SL used. In a clinical setting, however 40 dBSL is often utilized.

Riensche, Konkle and Beasley (1968) presented Form A of the Northwestern University Test 6 (NU-6 CVC monosyllables) to 80 normal hearing young adults at four sensation levels (8-32 dB) and five percentages of time compression (0-60%). The results for sensation level using NU-6 Form A showed that the performance decreased as a function of decreasing sensation level.

A study to generate speech intelligibility functions in a normal hearing population using the Auditec CID W-22 recordings with 30% and 60% time compression was conducted by Beattie (1986). The 30% condition revealed a slope of 3.24% per decibel and the function approached a plateau at 35 dB sensation level (SL). The 60% condition produced a function that increased gradually at 1-8% per decibel over the 20 to 80 % intelligibility range. An intelligibility score of 82% was observed at 46 dBSL where the function approached an asymptote. These functions provide a standard against which subjects with central auditory dysfunctions can be compared. The relative difficulty that normal subjects had with the 60% time compressed speech suggests that this condition may be too difficult for some subjects with APD.

Thus, there is general consensus that the scores of time compressed speech reduces with decrease in sensation level. It reaches a plateau at 32 dBSL. Clinically, 40 dBSL has been found to be most appropriate.

4) Effect of age

Nagafuchi (1976) presented distorted speech sounds to normal children age 4-11 years and to young adults in such a way that 20 monosyllables were distorted with a ‘speech stretcher’ that produced frequency and time expansion (150, 200, and 300%) and compression (30, 50, and 75%). The results revealed that discrimination ability clearly increased with age in normal children.

May, Rastatter and Simmons (1984) used 30 tape recorded sentences taken from the Carrow Auditory Visual Abilities Test, then time compressed by the lexicon Varispeech II to 50% in order to investigate age-related changes in auditory discrimination. Each sentence offered one or more phonemic contrasts (manner or place of articulation, voicing frequency, or some combination). Overall group mean performance was not different between 6 year- olds (N: 14) and 8 year olds (N: 20), or between 10 year olds (N: 16) and 15 young adults, but the 2 older groups were each significantly better than each of the 2 younger groups. The ontogenetic progression of this auditory processing ability seems to mature in the early part of the second decade of life of the five feature contrasts; only place of articulation was significantly more difficult, for all ages. Of the six frequency contrasts only that for high frequencies was significantly more difficult, for all groups, possibly due to an as yet undocumented damping of high frequencies by the time compression apparatus.

Gordon-Salant and Fitzgibbons (1993) investigated factors that contribute to deficits of elderly listeners in recognizing speech that is degraded by temporal waveform distortion. Young listeners aged 20-40 years (N: 10) and elderly listeners aged 65-76 years (N: 10), with normal hearing sensitivity and with mild-to-moderate, sloping sensorineural hearing losses were evaluated. Low-predictability (LP) sentences from the Revised Speech Perception in Noise test (Bilger, Nuetzel, Rabinowitz, & Rzeczkowski, 1984) were presented to subjects in undistorted form and in three forms of distortion: time compression, reverberation, and interruption. Percent- correct recognition scores indicated that age and hearing impairment contributed independently to deficits in recognizing forms of temporally distorted speech. The authors concluded that age-related factors other than peripheral hearing loss contribute to diminish speech recognition performance of elderly listeners.

Gordon-Salant and Fitzgibbons (1999) investigated age related performance differences on a range of speech and non-speech measures involving temporal manipulation of acoustic signals and variation of stimulus complexity. The goal was to identify a subset of temporally mediated measures that effectively distinguishes the performance patterns of 10 younger (18-40 years) and 10 older (65-76 years) listeners with normal hearing sensitivity and with sensorineural hearing loss. The speech measures were undistorted speech, time compressed speech (50% and 60%) reverberant speech, and combined time compressed (40%) reverberant speech. All speech measures were presented both in quiet and in noise. Age-related deficits were observed for all time-compressed speech conditions and some reverberant speech conditions, in both quiet and noise. Older participants exhibited poorer performance than younger participants on all conditions. Effects of hearing loss were observed also for the speech measures only. The findings of age related problems for recognition of time compressed speech independent of attenuation imposed by hearing loss, agreed with previous reports (Gordon–Salant & Fitzgibbons, 1993). The robust nature of the age effect with time compressed speech strongly indicates that aging imposes a limitation on the ability to process rapid speech segments.

In yet another study, Gordon–Salant and Fitzgibbons (2001) conducted an investigation to determine if the age related problem in recognition of time compressed speech could be attributed primarily to a decline in the speed of information processing or to a decline in processing brief acoustic cues. The role of the availability of linguistic cues on recognition performance was examined also. Younger subjects aged 21-34 years (14 normals and 10 hearing loss) and older subjects aged 65-72 years (13 normals and 14 hearing loss) participated in the experiments. Stimuli were sentences, linguistic phrases, and strings of random words that were unmodified in duration or were time compressed

(50%) with uniform time compression or with selective time compression of consonants, vowels or pauses. Age effects were observed for recognition of unmodified random words, but not for sentences and linguistic phrases. Analysis of difference scores of unmodified speech versus time compressed speech, showed age effects for time-compressed sentences and phrases. The forms of time compression that were notably difficult for older listeners were uniform time compression and selective time compression of consonants. The poor performance in recognizing uniformly time-compressed speech was attributed primarily to difficulty in recognizing speech that incorporated selective time compression of consonants. Hearing loss effects were observed also for most of the listening conditions, although these effects were independent of the aging effects. In general, the findings support the notion that the problems of older listeners in recognizing time compressed speech are associated with difficulty in processing the brief, limited acoustic cues for consonants that are inherent in rapid speech.

In an earlier study Luterman et al. (1966) reported of no effects. They compared the responses of 18 Spanish–American war veterans (79-87 years) to compressed and expanded PB word list with the responses of two control groups composed of 18 young hard-of-hearing subjects aged 20-40 years and 18 young normal subjects aged 20-38 years. The responses were obtained at two levels of compression, 10% and 20%. All subjects in this study responded in a similar manner to the time altered material. Neither the experimental nor the control group's discrimination ability improved with expanded speech, or at standard or increased response time intervals. Both levels of speech compression were determined to subject's performances relative to the unaltered condition. Possibly their contradictory findings were because they used much lesser levels of compression when compared to the other studies.

Studies have found that the discrimination ability of time compressed speech in children increases with age. The exact age upto which an increase in score is seen, is not clearly delineated in the studies that have been reported in literature. Each study has taken different age groups, thus making it difficult to compare across studies. However, in the case of adults the scores decline with age. This may be because aging imposes a limitation on the ability to process rapid speech segments.

5) Effect of Peripheral Hearing Loss

Stitch and Gray (1969) determined speech intelligibility scores for time compressed PB words for 28 young and old subjects having either normal (N=14) or sensorineural hearing losses (N=14). The compression levels used were 0%, 36%, 46%, and 59%. The discrimination of time-compressed words was not affected differentially by the nature of the subject’s hearing ability. This is because the disruptive effects of time-compressed speech are of central rather than peripheral origin. The major difference between the sensorineural and normal groups was that the performance of the former was attenuated across all compression ratios, including the 0% compression condition. Assuming that the high frequency losses in the sensorineural disorders are of a peripheral (receptor or first order neuron) nature, it would appear that such disorders serve to attenuate the baseline of performance, but are not particularly sensitive to distortions produced by the time compression of words. However, time compression attenuated the performance of the aged more than the young, and this difference increased as the amount of compression was increased.

Schon (1970) presented CID W22 monosyllables, compressed and expanded by ratios of 30 and 50% to five groups of 20 men each: young normal-hearing, young with normal hearing through 3 kHz, young with sensorineural hearing loss, aged with average hearing for their age and sex, and aged with sensorineural hearing loss. Intelligibility scores for all groups were depressed as compared to 0% compression/ expansion. Significant differences were noted for the young ears with sensorineural hearing loss and both groups of aged men in the compressions conditions as compared to the normal hearing young men. In the expansion conditions the intelligibility scores for the young and aged men with hearing loss were significantly different from the young normal group. Aged men with normal hearing for their sex and age were not significantly different from young normal men in the expansion conditions.

The effect of sharply sloping sensorineural high frequency hearing losses for comprehension was examined by Lacroix and Harris (1979). They studied forty-five subjects with a tape containing sentences that had been time compressed (250 words/ min) interrupted (50 msec on and 50 msec off) and masked with speech spectrum noise (+2 dB S/N) in that order. All subjects yielded normal speech reception thresholds, and generally normal scores in the Northwestern University Auditory Test No. 6. Distorted speech testing was done at 40 dBSL. Subjects with losses at 2 kHz and above were able to comprehend only 50, 65 and 68% of compressed, interrupted and noise-masked sentences, respectively. In contrast, subjects with losses at 3 kHz and above performed poorer than normal controls by 11.3, 12.5 and 8 percentage points respectively, while subjects within normal hearing sensitivity at 3 kHz performed as well as controls. The maximum dropped by 4.6 points with noise masking.

The findings that a hearing loss does effect perception of time compressed speech was also reported by Luterman et al. (1996), Gordon-Salant and Fitzgibbons (1993, 1999 & 2001). Thus, there is a general agreement that the presence of a peripheral hearing loss affects the scores of a time compressed speech test.

6) Effect of background noise

Riensche, Beasley and Lamb (1983) conducted an investigation that provided normative data for the intelligibility of time compressed (TC) phonemes in 40 normal hearing adults aged 18-26 years. Individual subjects were presented with 5 word rhyming sequences from the Fairbanks Rhyme Test (e.g. cat-bat-hat-mat-rat) sent to a monaural earphone at 40 dB re SRT, and were required to write the initial phonemes in the order as heard. Sequences were either at normal speed or at 66% TC, either unmasked or under contralateral multitalker masking at 65 dB re SRT, counterbalanced for ear (right, left) and presentation order (right-left, left-right). Significant effects of both TC and masking were obtained with separate analyses of item and order errors.

Bornstein (1994) studied the effect of speech time compression alone and in the presence of competing babble, in 24 adults and 24 children. Both adults and children showed significant decreases in speech recognition when speech was compressed at a rate of 60% as compared with recognition or normal rate of speech. Listening to time compressed speech in a binaural homophasic mode resulted in better speech recognition than in a monaural mode for both adults and children. When speech was antiphasic, both adults and children demonstrated a release from masking for normal-rate (0% compression) and 60% time compressed speech. When both groups listened to speech that had been compressed and presented in babble, their performance supported a multiplicative distortion theory. The results support the importance of binaural hearing for optimizing auditory performance in difficult listening situations.

The effect of time scale modification of speech on the speech recognition threshold in noise (SRTn) was investigated by Stollman and Kapteyn (1994). A group of 44 elderly subjects, varying in age from 56 to 88 years with sloping, mild to moderate sensorineural hearing losses were taken as subjects. The speech material consisted of six lists of thirteen short meaningful Dutch sentences, read by a female speaker. These sentences were then expanded by 37% and compressed by 27%, 35% and 48%. The authors found that time compression exerted a significant effect on SRTn and that the slope of regression lines for SRTn versus age increases with increasing time compression. Hearing sensitivity and maximum speech recognition in quiet was shown to be important predictors of variance in the measured SRTn values. The apparent age effect on relative SRTn is mostly caused indirectly by the significant correlation between age and PTA1, although there is a slight tendency for age to have a greater independent effect on relative SRTn values when the amount of time compression increases. Thus, the study confirmed the well-known fact that speech recognition in noise deteriorates with increasing age. Furthermore, results reveal that time compressing speech (27%, 35% and 48%) resulted in an even greater influence of age on the SRTn.

Thus, it is found that even for time compressed speech, masking deteriorates the performance. Studies also revealed that speech recognition in noise deteriorates with increasing age. This effect is enhanced if the stimulus is time compressed.

7) Effect of Language

Nikam, Beasley and Rintelmann (1976, cited in Beasley & Freeman, 1977) presented the Beasley et al. (1972b) stimuli to 144 normal hearing English Speakers/ listeners whose native languages were either Spanish or Indo-Dravidian. The Spanish speaker/ listeners had higher average scores than the Indo-Dravidian speaker/listeners. Further, the articulation functions for both groups were less steep (6.8% to 2.35%) than that found for the normal hearing English speaker/ listeners by Beasley et al. (1972b) (2.0% to 3.5% /dB). Nevertheless, the authors did suggest that the results could be used, with caution, when it was necessary to employ a measure of speech discrimination clinically with speaker/ listener whose native language was Spanish or Indo-Dravidian.

The performance of 16 South African English first and 16 South African English second language adult speakers on a series of auditory processing tests including 45% time compression was carried out by Saleh, Campbell and Wilson (2003).Their performances were descriptively compared to previously published American normative data. Comparisons between the South American English first and second language speakers showed equivalent performances on the left ear performance on the two pair dichotic digits test, and the frequency patterns test, the duration patterns test, the low pass filtered speech test, the 45% time compressed speech test, the speech making level difference test, and the consonant vowel consonant (CVC) binaural fusion test. A poorer right ear performance by the second language speakers on the two pair dichotic digits test only. Comparisons between the South American English and the American normative data showed many large differences, with the South American English speakers performing both better and worse depending on the test involved.

8) Effect of Speaker

Zemlin et al. (1968) conducted a study in which 40 normal college students rated the difficulty of listening to samples of speech subjected to 20, 30, 40 and 50% time compression compared with a standard consisting of normal speech. Male and female speakers were used. The male's speech was increasingly less difficult to listen to than the female's speech as the degree of time compression increased.

In order to study the effect of familiarity of the speaker on the perception of time compressed speech, Thompson and Silverman (1977) conducted an experiment. Of the 42 third grade children studied, 21 children, who formed the experimental group, had their teacher served as the speaker. A matched group of 21 children from another third grade classroom formed the control group. Each subject individually listened to a 940-word narrative passage that had been compressed at a rate of 45%. Ten questions about the material presented in the final three-fourths of the passage were asked of the subjects. The difference between the mean number of correct responses produced by the experimental group (5.5) and the control group (4.9) was not statistically significant. The results indicate that familiarity with the speaker does not facilitate 8-year-old's comprehension of time-compressed speech.

From these studies it can be noted that while a male speaker was found to be easier to perceive, the familiarity of the speaker had no effect on perception. However, due to the limited number of studies that have conducted studies on the effect of the speaker, these findings cannot be taken as conclusive.

9) List effect and effect of training

Beasley et al. (1972a) studied the effects of time-compressed monosyllabic CNCs on the auditory discrimination performances of 96 young adults with normal hearing. The experimental stimuli used in this study were the four lists of form B of the NU- 6 speech discrimination test. Five conditions of time compression, 30% through 70% in 10% steps, plus a 0% central condition were used. This resulted in 24 experimental tape recordings, six time-compressed recordings for each of the four lists. The lists were presented at four sensation levels (8, 16, 24 & 32 dB). List versions were counter balanced with these factors. Results indicated general decrease in intelligibility for all lists, except list IV, as the time-compression ratio increased. Specifically, this effect occurred beyond 0%, whereas at 0% time compression, there was essentially no list difference. The rather erratic configuration exhibited by list IV may be explained by simply noting that list IV sustained a greater degree of distortion before intelligibility declined. It was also found that list IV was the easiest, while list I appeared to be the most difficult. The interlist variability was greatest for the time compression ratios 40%, 60%, and 70%, whereas

30% and 50% show similar range of scores with less variability. As sensation level was increased, the interlist variability decreased. Again, list IV and list I appeared to be the easiest and most difficult, respectively.

Lack of list equality for the NU 6 tests was also reported by Grimes et al. (1984). They presented the four lists of the Audited of St. Louis recording of the 60% time-compressed No 6 test at 32 dB SL to 28 normal subjects and 28 subjects with sensori-neural hearing loss. One ear per patient was randomly selected and all four lists were administered. Subjects responded orally by repeating the stimulus word. The list order was counterbalanced and subjects assigned a specific ordering. At the conclusion of the experimental testing, a PI-PB function for the noncompressed NU 6 speech recognition test was administered. Significant list effects were found, the ranking of list difficulty, however, was similar for the normal hearing and sensorineural subjects. For both groups, significantly poorer scores were obtained when list III was used. Only lists I and IV were equivalent for both groups. The effects of learning did not appear to be a major clinical concern in administering the 60% time-compressed NU 6. Although a significant effect was observed for the normal group, no difference was noted between the first and second presentations. As normally only two lists are presented to a given patient, learning would not be expected to be a contaminant. For the sensorineural group, only a 4.5% mean improvement was noted across the four lists. Although this finding was statistically significant, it is unlikely that this small improvement would influence test interpretation.

Gade and Mills (1989) conducted experiments on the effects of brief prior exposure to time-altered speech on preferred listening rate and the rate listeners would select when asked to listen to speech as fast as possible with good compression (induced listening rate). In Experiment 1, 48 participants were exposed either to normal rate speech or to speech compressed to twice the normal rate. Brief exposure to twice the normal rate speech led to a faster induced listening rate than exposure to normal rate speech. In experiment 2, 31 participants were briefly exposed to normal speech rate, speech compressed to twice-normal rate, or speech expanded to half-normal rate. Speech compressed to twice-normal rate led to a faster induced listening rate than exposure to speech expanded to half-normal rate.

There seems to be an agreement that the lists of the NU 6 test, after compression, were not equal. However, there seems to be a lack of consensus as to the particular list yields a poorer score. An agreement however, exists that practice does improve the scores obtained.

10) Ear and Gender Effect

Beasley et al. (1972 a) also studied the difference in scores obtained as a function of the ear being tested. Results indicated minimal ear effects, which was not significant.

Nagafuchi (1976) presented distorted speech sounds to normal children in the age range of 4 to 11 years and to young adults. Twenty monosyllables were distorted with a ‘speech stretcher’, which produced frequency and time expansion (150, 200, and 300%)

and compression (30, 50, and 75%). There was no significant difference between boys and girls.

Ear and gender effects were also studied by Konkle, Beasley and Bess (1977). They time compressed (0, 20, 40, and 60%) and presented NU 6 words to four age groups ranging from 54 to 84 years of age. Experimental stimuli were presented at sensation level of 24, 32 and 40 dB to an equal number of right and left ears and male and female subjects. The results suggested a slight right-ear advantage for each group that increased with increasing time compression and age and decreasing sensation level. Within age groups there were essentially no differences between the performance of male and female subjects under the different sensation levels.

From the above review it is evident that there are several variables that affect the scores of a time-compressed speech test. There is a general agreement that the level of compression, sensation level, stimulus material, age of subjects, peripheral hearing loss, background noise, language, speaker, list of stimulus and amount of training definitely bring about a change in scores. It is important that these variables be kept in mind while constructing or administering a time compressed speech test.

Time Altered Speech and Clinical Population:

Time altered speech has been used on different clinical population for diagnostic purposes. These include brain damage, auditory processing disorder, learning disability, sickle cell anemia, specific language impairment, cluttering, articulation disorder, noise-induced hearing loss and mental retardation.

i) Brain damage/Aphasia

Kurdziel et al. (1976) administered tape recordings of time compressed (40 & 60%) monosyllables on eleven patients with diffuse unilateral temporal lobe lesion, four hemispherectomy patients, and sixteen patients with discrete unilateral temporal lobe lesion. Time compression was accomplished with the Fairbanks electromechanical apparatus, which allowed temporal compression but did not introduce frequency distortion. The results revealed that with 60% time compression, all patients with diffused unilateral cortical lesion shared breakdown of speech discrimination in the ear contralateral to the lesion. Patients with discrete unilateral cortical lesion generally did not demonstrate breakdown with the 60% time-compressed materials.

Rudnick and Berry (1975) presented 25 4-words, first and second-order sentential approximations to 18 aphasic and 18 normal children. The material was taped and altered to represent 5 speaking rates: 140 (normal); 75 and 105 (expanded); and 180 and 205 (compressed) words per minute. The order of presentation was randomized. The major difference between the children was that the second-order material was perceived best by normals regardless of rate, while the aphasics showed this preference only at the normal rate.

In a single case study, Oelschlaeger and Orchik (1977) presented audiological data for an 11-year-old aphasic girl with confirmed left-hemisphere damage. Pure-tone audiometry, impedance measurement, and speech discrimination testing was evaluated. Discrimination testing included presentation of the word intelligibility by picture identification (WIPI) test at 0 and 60% time compression. Results indicated significantly poorer speech discrimination in the ear contralateral to the site of lesion at 60% time compression. This case study supports the use of time-compressed speech discrimination testing in the assessment of central auditory function of children and as a diagnostic tool for determination of site of lesion.

Orchik, Walker and Larkson (1977) matched a group of eight aphasic adults in terms of age, sex, and peripheral hearing loss with non-aphasic adults. The two groups were compared on the WIPI, which was time-compressed at 0, 30 and 60%. Differences in discrimination were greatest at 60% time compression, where the aphasic groups mean discrimination scene was poorer than their matched controls by 30 percentage points.

From the literature it is evident that speech tests with a compression of 60% are useful in identifying processing problems in brain damage individuals. It was found to be more sensitive for diffused cortical lesions. The scores were found to be poorer for the ear contralateral to the site of lesion. Time compressed words are also found to be a good diagnostic tool to assess the processing abilities in individuals with aphasia.

ii) Auditory Processing Disorder

Manning et al. (1977) administered a time-compressed version of the PB-K 50 speech discrimination measure on twenty children (7.6 – 8.6 years) diagnosed as displaying auditory perceptual disorders. This measure was carried out at 0%, 30% and 60% time compression. The results indicated that as a group these children performed equally well at both 0% and 30% time compression, but their performance decreased significantly at 60% time compression. These results were compared with those obtained for normal children in a previously published paper (Beasley et al., 1976). This comparison indicated that the performance of the two groups of children was similar at the 30% time compression condition, but the auditory-disordered children's performance was poorer at both 0% and 60% time compression. These authors concluded that the results of the study might suggest that time compression of individual words facilitates the short term memory function of children with auditory processing difficulties, and 30% time compression of the speech stimuli employed in the study seemed to assist children with auditory perceptual problems to perform approximately as well as normals.

The performance of twenty-seven subjects with surgically, radiologically, or neurologically confirmed lesions of the central nervous system on time-compressed speech evaluated by Baran (1985). The subjects were administered a 60% time-compressed version of the NU-6 word lists. Subjects ranged in age from 12 to 59 years. Twenty-four subjects had normal hearing (25 dBHL or better) bilaterally at 500 to 4000 Hz. Three subjects demonstrated a mild hearing loss at a single frequency in one ear. Test stimuli were presented at 40 dBSL with reference to their speech reception thresholds.

Percent correct scores were derived for each ear and compared to norms previously established by Beasley et al. (1972b). Results revealed that in 67% of the subjects tested, performance in atleast one ear fell below established norms. For subjects with abnormal thresholds, performance was abnormal in the "better" ear, or in both ears in all three cases. These results suggested that a time-compressed speech test may be moderately useful in the identification of CNS lesions.

Karlsson and Rosehall (1995) evaluated the clinical validity of four different low-redundant speech tests using four groups of 83 patients with retro cochlear or central auditory lesions. The speech tests used were interrupted speech (7 and 10 interruptions/s); time compressed speech (message compressed to 290 words/minute) and filtered speech. A comparison between patients and age matched normal-hearing controls showed that the patients had significantly lower speech recognition score. The speech tests with the highest sensitivity were 7 interruptions per sec and time-compressed speech. Time compressed speech was found to have the following sensitivity levels for different lesions: 67% (cerebelopontine angle tumors), 64% (brainstem lesions), 47% (vascular brainstem lesions), and 80% (temporal lobe lesions).

The usefulness of time-compressed speech in determining the presence of an auditory processing disorder was demonstrated by Riensche, Curran and Porch (1986). They selected normal-hearing children (39M, 36F) from a monolingual environment, aged 5 years 10 months to 7 years 10 months, having an average or better intelligence, as being at high, average or low risk of reading readiness according to score on the

Lindamood Auditory Conceptualization (LAC) test. Subjects were also given the Stephens Oral Language Screening Test (SOLST), emphasizing syntactical development. They were then tested for exhale repeating of taped 5- word sentences and 5-word first-order sentenced approximations at 32 dB SL with reference to SRT. Stimuli were presented at 0, 40 or 60% time compression. Responses were scored right/wrong and also by Porch's multidimensional system involving repeats and cues. For both responses (right/wrong or repeating) significant effects were obtained between the different time compressions versus both the LAC and SOLST. The LAC appeared to emphasize phonetic units and the SOLST linguistic units in real sentences. The TC condition appeared to emphasize linguistic units at both word and sentence levels, less so with increasing TC. Results supported the usefulness of the TC stimuli in assessing reading readiness and it was suggested that the various stimuli assess different aspects of auditory processing.

Ferre and Wilber (1986) examined the performance of normal children (N=13) and learning disabled children (N=26) on an experimental battery of central auditory processing (CAP) tasks. The battery included between pass-filtered speech (LPFS), binaural fusion (BF), time-compressed speech (TC, 60%), and dichotic monosyllables (DM) test. The learning disabled subjects were classified as having normal (LD/N) or significantly impaired (LD/LD) auditory perceptual skills on the basis of a pretest battery of auditory language tests. The normal (N/N) subjects and non-auditory learning disabled (LD/N) subjects tended to perform alike across measures. The auditory impaired (LD/LD) subjects tended to perform significantly poorer than their normal age mates.

The TC speech test correctly identified 62% of the LD/LD subjects. However, 62% of the subjects judged to have normal auditory processing skills (LD/N) also failed the TC test while all the normal subjects passed in the test. This suggests that a time compressed speech test is less useful clinically.

Studies reveal that children with auditory processing deficit perform poorer than their age matched normal children. Time compressed words were found to be most sensitive in identifying temporal lobe lesions. There are also studies reported in literature that signifies the efficacy of time-compressed words in identifying auditory processing deficits in children with learning disability. However, one study reports that this test is less useful clinically because learning disabled children even without processing deficits failed in the test. This discrepancy in the results can be attributed to the lack of homogeneity seen in the learning disabled population.

iii) Learning Disability

Time compressed speech has been used quiet extensively in evaluating children with learning disability. It most often has been used as a part of test battery. The test continues to be popular even in the present day.

Freeman and Beasley (1978) compared the performance of 20 normal-reading and 20 reading-impaired children using time-compressed three-and five-word sentential approximations to full grammaticality, and the Word Intelligibility by picture identification (WIPI) test presented with and without pictures. The compressions levels used were 0% and 60%. The reading-impaired group presented a wider array of scores, particularly at 60% time compression on the five-word first-and second-order sentential approximations. They demonstrated a 12.4% difference between 0% and 60% time-compression for the closed-set format, and a 20.4% difference between scores on the non-visual open-set format. The procedure of comparing the discrimination scores obtained at 0% and 60% time compression thus might provide more diagnostic information than simply computing the percentage of correct responses at a specific level of time compression and comparing those results to a norm.

Watson, Stewart, Krause and Rastaller (1990) measured the ability of eight good and eight poor readers (in Grade 1, ages ranging from 6.7 to 7.4 years) to discriminate phonemic contrasts presented in 50% time-compressed sentential stimuli (sub test 13 of the (Arrow-Auditory Visual Abilities Test). Good readers exhibited a significantly higher over-all mean performance than poor readers on the time-compressed task. Effects of time-compression on the perception of manner, place, voicing and frequency contrasts showed a similar pattern of errors for both groups of readers.

Bornstein and Musiek (1992) studied the effects of listening to time-compressed speech alone and in a competing babble, with speech in and out of phase between ears, in ten children with no apparent auditory or learning problems and in ten children with learning disabilities and a suspected central auditory processing problem. The children ranged in age from 8 to 10 years. Both groups showed significant decreases in speech recognition when speech was compressed at a rate of 60% as compared with recognition of normal-rate speech. However, the children in the learning disabilities group showed a greater decrease. Listening to time-compressed speech in a binaural mode resulted in better speech recognition than in a monaural mode for both groups. When speech was shifted 180 degrees out of phase between ears, both groups demonstrated a release from masking for speech presented at a fast rate (60% compression), but the normal group had a greater release from masking than the learning disabilities group. Also, the learning disabilities group did not show a release from masking for normal-rate speech (0% compression). When both compressed and presented in babble, their performance supported a multiplicative distortion theory, with children in the learning disabilities group showing a slightly greater multiplicative effect than the children with no apparent problems. The results support the necessity of binaural hearing to maximize auditory performance in difficult listening situations in two populations of subjects.

Many people with developmental dyslexia have difficulty perceiving stop consonant contrasts as effectively as other people and it has been suggested that this may be due to perceptual limitations of a temporal nature. Accordingly, Anally, Hansen, Cornelissen and Stein (1997) predicted that perception of such stimuli by listeners with dyslexia might be improved by stretching them in time-equivalent to speaking slowly. Concisely, their perception of the same stimuli ought to be made even worse by compressing them in time-equivalent to speaking quickly. They tested 15 children with dyslexia on their ability to identify correctly consonant-vowel-consonant (CVC) stimuli that had been stretched or compressed in the time domain. They also tested their perception of the same CVC stimuli after the formant transitions had been stretched or compressed in the frequency domain. The performance reduced with increase in compression but contrary to their prediction, they failed to find any systematic improvement in their performance with expansion. They conclude that simple manipulations in the time and frequency domains are unlikely to benefit the ability of people with dyslexia to discriminate between CVCs containing stop consonants.

Thus, literature reveals that children with learning disability perform poorer with increase in the level of time compression. It is also found that difference between the scores of 0% and 60% compressed words can be better diagnostic criteria for such children. The learning disabled children did not show a release from masking for compressed words as is seen in normal subjects. Hence, time compressed words are found to be highly sensitive in identifying children with dyslexia.

iv) Other disorders

Sickle Cell Anemia: The effect of sickle cell anemia on auditory processing has not been studied much. Sharp, Daniel and Orchik (1978) assessed the auditory function in nine black subjects with sickle cell anemia and compared them with a central population (9 subjects). No differences were found for measures of hearing acuity and undistorted speech discrimination. However, some suggestion of reduced neural function was observed in terms of acoustic reflex measures and time-compressed speech discrimination (0% and 60% compressed). The time-compressed speech discrimination scores for the group with sickle cell disease were on the average about 5% poorer in the left ear, and the difference increased to 15% in the right ear as compared with those of the control group. This slight but consistent right ear difference was not seen in the control subjects. In five of the seven subjects with sickle cell disease, for who time-compressed speech discrimination scores were obtained, right ear scores were reduced relative to the left by 12% or more. The reason for this may be because patients with central auditory lesions have demonstrated reduced performance in the ear contralateral to the lesion or bilaterally reduced discrimination scores (Kurdziel & Noffsinger, 1973, cited in Sharp et al., 1978; Orchik, Walker and Larson, 1977). Only two control subjects showed a similar right ear asymmetry.

Specific Language Impairment: Stollman, Kapteyn and Sleeswijik (1994) measured the effect of time-compression and expansion of speech on speech perception in noise for a group of hearing-impaired and a group of language-impaired children relative to control groups of normal children and normal adults. The children's age ranged from 9 to 12 years. For all time-scale modified conditions (37% expansion, 27%, 35% and 48% compression), both hearing-impaired and language-impaired children had significantly higher speech recognition thresholds in noise (SRT_N) than their normal peers, who performed almost equally as the adult control group. Time-expansion was shown to have a negligible effect on SRT_N for all groups when compared to the control condition, i.e. 0% time-compression. The difference in SRTn between the control and the impaired groups was in general, not significantly altered by the degree of time-compression or expansion of speech, although a clear trend towards greater differences for increasing time-compression was observed. Five tests of auditory discrimination and auditory memory were also administered to both groups of impaired children. In a stepwise multiple regression procedure, 94% of variation in SRT_N in the central condition could be explained by the score on a word discrimination test (ADIT C) and the maximum speech recognition score for monosyllables in quiet.

In a recent study, Suchodaletz, Albeti and Berwanger (2004) examined 23 language-impaired children and 52 controls aged 7 to 11 years. Auditory abilities were measured by means of a battery of nonverbal and verbal tests. The children had to identify tones of different frequencies, loudness, duration or patterns as well as every day sounds and mixtures of such sounds. Noise-overlaid, time compressed and frequency-limited speech tasks and binaural summation tasks were also used. In addition, phoneme discrimination ability and auditory memory were assessed. Language impaired children scored low on phoneme discrimination and auditory memory tests but not a nonverbal or verbal auditory perception tasks. A significant correlation between their expressive language ability and their scores on phoneme discrimination, auditory memory, and sound duration identification tests were obtained. The results do not support the assumption that developmental language disorders are associated with auditory perception deficits. However, there are indications that auditory memory and time processing are deficient. Thus, training of auditory perception does not appear to be a suitable treatment for language impaired children.

Cluttering: Blood, Blood and Tellis (2000) conducted a study in which they examined the differences among scores on four tests of auditory processing of six children who had cluttering and six control subjects matched for age; sex, and grade. No differences were found between groups for the auditory-attention task and the time-compressed speech task. Scores on a consonant-vowel dichotic listening task indicated that directing the attention of the attended ear improved the percentage of correct response for both groups of children. Those who cluttered, however, showed a greater percentage of change during the directed right and left ear conditions. Cluttering children performed poorer on right and left competing conditions of the staggered Spondaic Word Test.

Articulation disorder: Oelschlaeger and Orchik (1977) time compressed the word intelligibility by picture identification (WIPI) Test of Speech Discrimination at 0, 30, and 60% and administered it to 48 normal-hearing children. The children all between the ages of 5 years 6 months and six years 7 months of age were equally divided into three groups on the basis of articulation ability. Significant effects were found for test groups and levels of time compression, with differences increasing as time compression increased. Children with multiple articulation errors demonstrated a developmental lag in the ability to process time-compressed speech. Authors concluded that time-compressed speech may be a useful tool in the study of auditory perception in children.

Riensche and Clauser (1982) took 12 children who had satisfactorily completed therapy for 47 phonemes, and normal controls, they were given tasks of auditory perception consisting of (a) repeating 5-word recorded sentences (0, 1st and 2nd – order approximations) at 0 and at 60% time compression, and (b) dichotic and diotic presentations at 40 dB SL of the WIPI test split into 2 bandwidths (500-580 and 1950-2080 c/s). Results showed that the performance of the experimental subjects was significantly poorer than that of age-matched controls on time-compressed speech, but not on the binaural fusion task. The greatest diagnostic potential for time-compressed speech was at 60% compression.

Noises-induced Hearing Loss: The effects of time compression on the intelligibility of consonant-nucleus–consonant (CNC) monosyllables on subjects with a noise-induced sensorineural hearing loss was investigated by Kurdziel et al. (1975). They presented six conditions of time-compressed versions of the Northwestern University Auditory Test No. 6 at four sensation levels, to nine subjects. Results indicated that intelligibility gradually decreased as the ratio of time compression increased, with a dramatic break down at the highest ratio of time compression.

Mental Retardation: Mentally retarded adolescents and mental age-matured non-retarded children participated in three experiments designed to examine differences in language-processing efficiency by Merril & Mar (1987). A compressed speech technique was used in Experiments 1 and 2. Experiments 3 relied on a sentence–picture verification procedure. The results suggested that retarded and non-retarded individuals differ in the speed with which they are able to execute the semantic analytic processes but not necessarily the phonological encoding processes that are involved in auditory language comprehension. In addition, the data suggested a possible group difference in the quality of the semantic representation encoded during sentence processing.

The review of literature brings to light that there are several variables that influence the scores of a time compressed speech test. It is essential that these variables be considered while developing a time compressed speech test. It is also evident from the literature that a time compressed speech provides useful information regarding the presence of an auditory processing problem in various conditions such as brain damage, learning disability, sickle cell anemia, specific language impairment, cluttering, articulation disorder, noise induced hearing loss and mental retardation. The majority of studies have reported that at a compression level of 60%, a clear-cut difference in the performance of a normal and deviant population is obtained. In view of the utility of the test, in diagnosing auditory processing problems, it is essential to develop the test in different languages.

METHOD

The present study aimed at developing a time compressed speech test in English for Indian children. The effect of ear, gender, level of compression and age was studied. Normative data for different age groups across compression levels was also developed. Other variables like speaker, presentation level, stimulus material and language were kept constant.

Subjects:

The subjects for the study were a group of 80 normal children (40 boys and 40 girls) in the age range of 7-12 years. These subjects were divided into five age groups (7-7.11 years, 8-8.11 years, 9-9.11 years, 10-10.11 years and 11-11.11 years). Each group had 8 boys and 8 girls.

To be selected as subjects, they were required to fulfill the following criteria:

- Should have English as a medium of instruction for at least one year,
- Should not have any history of developmental delay,
- Should not have any history of hearing loss and speech problems,
- Should not have any history of otological or neurological problems,

- Hearing sensitivity should be within normal limits (i.e. air conduction threshold of less than or equal to 15 dBHL in the frequency range of 250-8000 Hz in both ears and the air bone gap less than 10 dBHL at any frequency),
- Should not have any illness on the day of testing,
- Speech identification scores should be more than or equal to 90%,
- Should not have any history of poor academic performance,
- Should pass the Screening Checklist for Auditory Processing (SCAP) developed by Yathiraj and Mascarenhas (2003) was administered to rule out any kind of auditory processing deficit.

Development of test material:

"Monosyllabic Speech Identification Test in English for Indian Children" developed by Rout and Yathiraj (1996) was used. It consists of two lists and each list has 50 English monosyllables. Further, each list had two equal half lists. The four half lists were recorded in a Pentium IV computer. The recorded material was then edited using the "Creative Mixer Sound Blaster 16" software. Scaling of the signals was done using the "Audio Lab" software to ensure that the intensity of all sounds was brought to the same level.

After scaling these lists were then time compressed using Praat software. Four compression levels were used for the four lists i.e. 0%, 40%, 50% and 60%.

A 1 kHz calibration tone was recorded before each list for VU meter calibration. The output of the computer was recorded onto audio CD (CD_R 700 MB) using Easy CD Creator software. HP CD-Writer + 8200 was used to record the CD.

Instrumentation:

The preliminary tests were done using a clinical audiometer Madsen OB 922 which was coupled to a TDH-39 earphone housed in MX-41/AR ear cushions, for air conduction. Bone conduction testing was done using Radio Ear B-71 BC vibrator. The audiometer was calibrated according to ANSI standards (1991, cited in Wilber, 1994).

For the time compressed test, the audio CD was played on a CD player (Philips DVD729K), the output of which was fed to the tape input of a clinical audiometer (Madsen OB922). The output of the audiometer was given through the TDH-39 earphones housed in MX-41/AR ear cushions.

Environment:

The test was carried out in an air conditioned sound tested double room suite with ambient noise levels with in permissible levels (re: ANSI, 1991, as cited in Wilber, 1994).

***Procedure*:**

i) For subject selection:

SCAP was administered on children from primary and middle schools in Mysore city and those who passed the checklist and met the criteria were selected. Pure tone AC and BC thresholds were obtained using a modified Hudson-Westlake procedure. AC thresholds were obtained for frequencies 250-8000 Hz and BC thresholds were obtained for frequencies 250-4000 Hz.

ii) For obtaining normative data

Those subjects who passed the subject selection criteria were administered the time compressed speech test. The test was administered at 40 dBSL monaurally. Prior to the presentation of the lists, it was ensured that VU meter deflected to zero, using the 1 KHz calibration tone. All the four half lists were presented to each subject. Thus, all subjects heard all four levels of compression. The lists were randomized to avoid the order in which the subjects heard the different levels of compression. Half of the subjects were tested in the right ear and other half on the left ear in order to avoid an ear effect. The subjects were asked to repeat what they heard and the tester recorded the response.

Scoring:

The responses were scored in terms of number of correct responses for different percentages of compression.

The scores were statistically analyzed. Mean standard deviation and confidence intervals were found out for different levels of compression for all the age ranges. MANOVA (Hotelling’s trace and test of between subject effects), Duncan’s Post HOC test and repeated measure ANOVA was done in order to find the significance of difference for means.

RESULTS AND DISCUSSION

In this section, the results obtained from the present study are discussed. Statistical analysis was done to obtain information on the following using the SPSS (version 10.0) software:

i) Ear effect

ii) Gender effect

iii) Effect of level of compression

iv) Age effect

Each of the above aspects were analyzed using MANOVA. In addition, age effect was analyzed using, Duncan's Post hoc and repeated measure ANOVA. The normative data for each age group was found out by calculating mean, standard deviation and confidence interval across levels of compression.

i) EAR EFFECT

The difference in the right ear from the left ear was determined across age groups by calculating the mean and standard deviation (Table-1). MANOVA (Hotelling's trace and test of between-subjects effects) was done in order to find out the effect of the ear being tested, on the scores. The results indicated that the ear effect was not significant (F (4, 57) = 0 .553, $p > 0.05$). No statistical significant difference was noted between the two ears at any of the age groups or compression levels.

Table-1: Mean and standard deviation for right and left ears, males and females across age groups for different levels of compression.

			Mean		Std. Deviation	
	AGE	EAR	male	female	male	female
0%	7-7.11	right	20.50	21.75	1.73	1.50
		left	22.25	22.75	3.59	.50
	8-8.11	right	21.25	21.00	2.63	.82
		left	21.50	22.00	2.65	.82
	9-9.11	right	24.00	24.00	.82	1.15
		left	22.75	23.75	2.22	.50
	10-10.11	right	21.50	21.00	2.08	1.41
		left	23.25	22.50	.50	.58
	11-11.11	right	23.50	24.25	.58	.96
		left	22.50	24.50	.58	.58
40%	7-7.11	right	15.25	19.75	5.56	2.99
		left	20.00	21.00	1.41	2.71
	8-8.11	right	21.00	18.00	2.45	2.16
		left	19.75	22.00	4.43	1.41
	9-9.11	right	20.25	22.50	.96	1.29
		left	20.25	22.00	.50	1.41
	10-10.11	right	21.75	22.25	1.50	.96
		left	21.75	21.75	.96	1.71
	11-11.11	right	23.50	23.75	.58	.50
		left	21.50	22.25	1.29	1.71
50%	7-7.11	right	16.00	19.00	3.37	1.41
		left	18.50	17.00	1.91	4.08
	8-8.11	right	19.50	15.50	2.52	1.73
		left	18.25	19.00	2.87	1.15
	9-9.11	right	18.50	19.25	4.93	4.50
		left	21.50	21.75	.58	.96
	10-10.11	right	18.00	20.50	.82	1.73
		left	18.75	20.25	4.72	3.40
	11-11.11	right	20.50	22.50	1.29	1.29
		left	17.00	20.75	1.63	3.50
60%	7-7.11	right	12.50	19.00	1.91	2.00
		left	18.50	19.25	3.11	1.50
	8-8.11	right	16.00	17.50	.82	2.65
		left	16.75	17.00	3.77	3.74
	9-9.11	right	20.00	19.00	1.41	2.00
		left	17.25	19.50	1.71	.58
	10-10.11	right	20.00	17.50	1.41	1.00
		left	18.75	20.00	2.99	2.45
	11-11.11	right	21.75	20.25	1.71	.96
		left	17.00	20.00	1.15	2.94

The results obtained from the present study are consistent with results of a study conducted on the Western population by Beasley et al. (1972a). Beasley et al. (1972a) reported that there existed no differences between right and left ear scores at several conditions of time compression. They postulated that in order to validly use the same test for both right and left ears, performance of normal subjects would warrant that test results between ears be essentially equal. The question of differences between ears is therefore worthy of consideration in light of the potential utility of time-distorted speech as a diagnostic tool for central auditory disorders.

Under dichotic listening conditions, right ear superiority was found for speech stimuli whereas for non-speech stimuli, the left ear performance was found to be better (Kimura, 1967, cited in Bellis, 1996). This is because dichotic tests checks for hemisphere dominance. However, studies of monotic listening tasks (Dirks, 1964; Glorig, 1958, cited in Bellis, 1996) have failed to reveal clinically significant right (dominant) ear effects, as they do not check for hemisphere dominance. These monotic findings were supported by the study conducted by Beasley et al. (1972a), suggesting that time compressed speech can be clinically utilized in a monotic listening task without being confounded by ear laterality effects.

Thus, the results of the present study indicated that there existed no significant difference between the two ears for the monotically presented time compressed stimuli even in the Indian population.

ii) GENDER EFFECT

The difference in the scores of males and females was determined for all age groups by calculating the mean and standard deviation (Table-1). MANOVA (Hotelling's trace and test of between-subjects effects) was done in order to find out the effect of gender on the time compression scores. The results indicated that gender effect was not significant (F (4, 57) = 1.551, $p > 0.05$). This gender difference was not seen across the different age groups as well as different compression levels.

Similar results were reported by Nagafuchi (1976). It was noted that even though other studies have shown that girls may be more proficient in discriminating speech sounds during the developmental period, there was no significant difference found between the performance of boys and girls of age 4-11 years, in time compressed speech test.

Similar findings have been reported in a study conducted by Konkle et al. (1977). They measured the speech discrimination ability in adults (54-84 years) at different sensation levels and different levels of compression. They found that within age groups there were essentially no differences between the performance of male and female subjects under the different time compression and sensation level conditions. This proves that the central aging process takes place equally in both males and females. They also found no significant difference in the performance of males and females at different levels of compression.

Studies have shown that young girls, aged 1-5 years, are more proficient in language skills, talk at an earlier age, produce longer utterances, and have larger vocabularies than do boys (Ruble & Martin, 1998, cited in Plotnik, 1999). Although there appears to be a gender difference in verbal abilities favoring women, this difference is relatively small and thus has little practical significance (Hyde, 1994, cited in Plotnik, 1999).

Thus, the results of the present study are in agreement with earlier studies, indicating that there exist no significant difference between the performance of males and females across age at different levels of compression. Hence, it can be construed that boys and girls in the age range of 7 to 12 years develop in a similar manner, with respect to the way in which temporal processing takes place.

iii) EFFECT OF LEVEL OF COMPRESSION

MANOVA (test of between-subjects effects) was done in order to find out the effect of level of compression on scores. The results indicated that the scores differed significantly across different compression levels (Table 2). The mean scores decreased from 21.81 (87.2%) to 17.31 (69.2%), for 0% to 60% compression, in the youngest age group. Likewise in the oldest age group the scores decreased from 23.69 (94.7%) to 19.75 (79%).

In a study conducted by De Chicchis et al. (1981), the mean scores obtained by 18-28 years old adults decreased from 92.7% to 73.7%, for 0% compression to 60% compression. The scores obtained by the older children in the present study are similar to that reported by De Chicchis et al. (1981).

However, results reported in a study by Riensche et al. (1976) are not in total agreement with the findings of the present study. In their study it was found that the mean scores reduced from 97.5% to 89.9%, for 0% compression to 60% compression. Their study was conducted on for adults aged 18-26 years. While the scores for the 0% compression is not very different from the scores of the present study and that of De Chicchis et al. (1981), their scores for the 60% compression are much higher. A possible reason for this discrepancy at 60% compression level could be attributed to the segmental cues that are deleted during time compression. Possibly the lists that result in poorer score, had segmental cues deleted which were essential for speech perception. However, the lists that did not have poorer scores may not have essential segmental cues deleted, thus resulting in better perception. Possibly in the study conducted by Riensche et al. (1981) they did not cut the major segmental cues, resulting in better scores even for higher compression levels.

Table –2: F values, degrees of freedom and significance of difference for different compression levels across age

	Level of Compression	**df**	**F**
Age	0%	4	7.193**
	40%	4	6.950**
	50%	4	3.027*
	60%	4	5.181**

* ($p < 0.05$) and ** ($p < 0.01$).

These results of the present study are also consistent with results found by Foltner et al. (1979). They found that responses were significantly different for different levels of compression. Similar results were also reported by Riensche et al. (1976), DeChicchis et al. (1981) and Beattie (1986).

With increase in compression level, the amount of external redundancy decreases, making it difficult for the listener to perceive the speech signal. As a consequence perception scores decreases with increase in compression level. Thus, the results of the present study indicated that the performance of time-compressed words is significantly different across levels of compression. Hence, during clinical application of a time compression test, it is essential that the scores obtained on a client be compared with norms of appropriate levels of compression.

iii) AGE EFFECT

MANOVA (Hotelling's trace and test of between-subjects effects) was done in order to find out the effect of age on scores. Since there was no ear and gender effect seen, all the scores were combined together. The results of MANOVA indicated that the effect of age was highly significant ($F (16, 222) = 3.427$, $p < 0.01$). Duncan's Post hoc test was done between the different age groups, across compression levels, to get more age specific information.

From Table 3 it is evident that for the 0% compressed words, the younger age groups were significantly different from the older age groups. One exceptional performance was seen in the 10-10.11 years age group, who had scores similar to the youngest group. Thus, it can be noted that the development in perception of noncompressed speech does not take place in a linear fashion. This can be because of individual variability seen in scores.

There was a definite developmental trend seen for the 40% compressed words. The younger age groups were significantly different from the older age groups. There was no significant difference seen for the adjacent age groups but it was present for children whose ages were at least two years apart.

Table-3: Level of significance between different age groups, across compression levels

Age in Years	**Level of Compression**			
	0%	40%	50%	60%
7-7.11 Vs. 8-8.11	NS	NS	NS	NS
7-7.11 Vs. 9-9.11	0.01	0.05	0.05	0.05
7-7.11 Vs.10-10.11	NS	0.01	NS	0.05
7-7.11 Vs.11-11.11	0.01	0.01	0.05	0.05
8-8.11 Vs. 9-9.11	0.01	NS	0.05	0.05
8-8.11Vs.10-10.11	NS	0.05	NS	0.05
8-8.11 Vs. 11-11.11	0.01	0.01	0.05	0.01
9-9.11 Vs. 10-10.11	0.01	NS	NS	NS
9-9.11 Vs. 11-11.11	NS	NS	NS	NS
10-10.11 Vs. 11-11.11	0.01	NS	NS	NS

For the 50% compressed words also the younger groups were significantly different from the older group. Once again the 10-10.11 year olds performed differently. The scores of this age group were not significantly different from any of the age groups. This can be attributed to the individual differences as was seen for the 0% compressed words.

As can be seen from Table 3, 60% compressed words showed a distinct developmental trend. The younger age groups (7-7.11 and 8-8.11 years) were found to be significantly different from all the older age groups. There was no significant difference in age groups after 9-9.11 years, showing a plateau effect.

Thus, it can be concluded that as the difficulty of the task increases, a definite development trend can be seen. When the words were 0%, 40% and 50% compressed, there was no distinct developmental trend seen across ages because the task was easier. However, at 60% compressed condition, the younger and older age children got significantly different scores and a developmental trend was seen. This can be attributed to the difficulty of the task. Hence, it can be noted that for difficult tasks, younger and older children perform differently.

These results are consistent with the results from the study of Nagafuchi (1976). He found out the scores for time compressed monosyllabic words in normal children aged 4-11 years. The results revealed that the intelligibility improved gradually with increasing age and a significant difference was found between the ages 9 and 10 years. The discrimination scores of different subjects, in a test with the same experimental condition, differed considerably. However, the scores of the same subject did not differ so much in all tests. Moreover, with increasing age, the dispersion of individual discrimination scores became smaller. The result suggested that the auditory perception of younger children might be imperfectly developed.

Similar results were reported by Beasley et al. (1976). They found that the mean intelligibility scores increased as age increased. On the more difficult measure the decrease in intelligibility for all age groups was similar as a function of time compression. In contrast, for the easier measures where the compression level is less, the scores of younger and older groups were similar. So, they concluded that as the degree of difficulty is increased by increasing time compression, the younger children performed progressively worse than the older children, particularly on the more difficult measure.

Thus, the results of the present study indicate that there existed significant difference between the age groups across different levels of compression. The younger group performed worse with increase in difficulty of task. For lesser levels of compression (0%, 40% and 50%) there was an overlap seen among the scores of some younger and older children. However, for higher compression (60%) there was a clear developmental trend seen with the younger group performing poorer than older group and the cut off was seen at 9-9.11 years. The 9-9.11 years old children performed similar to the older two age groups.

The distinct developmental trend seen for the difficult listening condition (60% compression) shows that for higher level temporal processing, maturation continues till 9-9.11 years. Using easier listening tasks (less than or equal to 50% compression) this higher-level maturation cannot be clearly tapped.

Effect of compression within an age group

In order to find out if there was a significant difference for different levels of compression in a particular age group, repeated measure ANOVA (Bonferrori multiple comparison) was done.

Table 4 gives the F values, degrees of freedom and significance of difference of means for different age groups, across different levels of compression. As can be seen from this table all the levels of compression were significantly different from each other in all the age groups. Hence, when testing children of different ages, it is essential that age appropriate norms be referred. Within each age group their performance across different levels of compressions can be divided into subsets based on the confidence interval.

Table – 4: Degrees of freedom, F values and significance of difference of means for different compressions within age group

Age Groups (in years)	**df**	**F**
7-7.11	3	11.534**
8-8.11	3	20.089**
9-9.11	3	17.658**
10-10.11	3	12.945**

Note: ** ($p < 0.05$).

Table 5 provides information regarding the mean, SD, confidence interval (95%) and range. Similar information is also provided in Figure 1-5. These figures give the error graph for each age group. The graphs show the mean values and confidence intervals for each compression level within an age group. Information from Table 5 and Figures 1-5 could serve as normative data. Based on this information, it can be determined, whether the scores of a client on the time compressed test are normal or deviant.

From the information in Table 5 and Figure 1-5 it can be seen that the performance for time-compressed words reduced with increase in the level of compression for all the age groups. The children in the age range 7-7.11 years showed an overlap in the scores for compressions of 40%, 50% and 60% while their performance on 0% compression is different. Thus, this age group performs poorly even with a slight amount of compression (Figure-1).

In Figure-2 it is evident that for the eight year olds, the adjacent compression levels are not significantly different from each other. Whereas for 9-9.11 year olds, 0% compressed words can be put in one subset, 40% and 50% in another subset, and 50 % and 60% in the third subset (Figure-3). The possible reason for this can be that 50% compressed words were found to have a wider confidence interval in this particular age group (Table 5 & Figure 3). This is in turn because of a wider gap in-between the minimum and maximum value, which can be attributed to the individual variability in scores. This is evident in Table 5.

In the 10-10.11 year olds, the error graph indicates that the 0% and 40% compressed words can be put in one subset whereas 50% and 60% compressed words can be put in another subset (Figure-4). Similar results were noted for the 11-11.11 year olds (Figure-5).

Table –5: Mean, SD, Confidence Interval, Minimum and Maximum scores for all age groups at different levels of compression

Age in years	**Level of compression**	**Mean***	**Standard Deviation**	**95% confidence Interval**		**Range**	
				Lower Bound	**Upper Bound**	**Minimum**	**Maximum**
7-7.11	0%	21.81	2.10	20.69	22.93	17	25
	40%	19.00	3.88	16.93	21.07	7	23
	50%	17.63	2.87	16.09	19.16	12	22
	60%	17.31	3.50	15.45	19.18	10	23
8-8.11	0%	21.44	1.79	20.48	22.39	18	24
	40%	20.19	2.97	18.60	21.77	18	24
	50%	18.06	2.52	16.72	19.40	13	22
	60%	16.81	2.74	15.35	18.27	13	22
9-9.11	0%	23.63	1.31	22.93	24.32	20	25
	40%	21.25	1.44	20.48	22.02	19	24
	50%	20.25	3.36	18.46	22.04	13	25
	60%	18.94	1.73	18.02	19.86	15	22
10-10.11	0%	22.06	1.48	21.27	22.85	19	24
	40%	21.88	1.20	21.23	22.52	20	24
	50%	19.38	2.94	17.81	20.94	12	25
	60%	19.06	2.17	17.90	20.22	15	23
11-11.11	0%	23.69	1.01	23.15	24.23	22	25
	40%	22.75	1.39	22.01	23.49	20	24
	50%	20.19	2.81	18.69	21.68	15	25
	60%	19.75	2.44	18.45	21.05	16	24

*Maximum score = 25

Figure-1: Error graph for 7-7.11 years

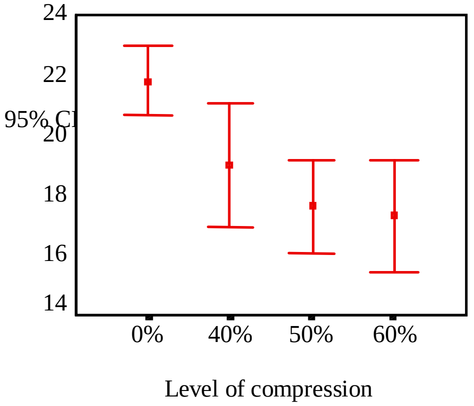


Figure-2: Error graph for 8-8.11 years

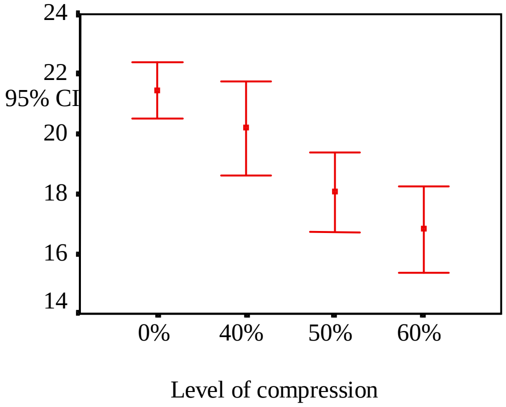


Figure-3: Error graph for 9-9.11 years

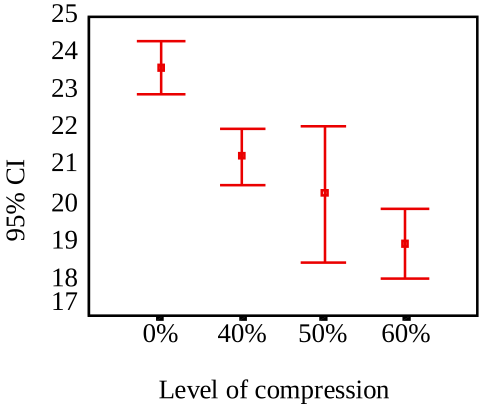


Figure-4: Error graph for 10-10.11 years

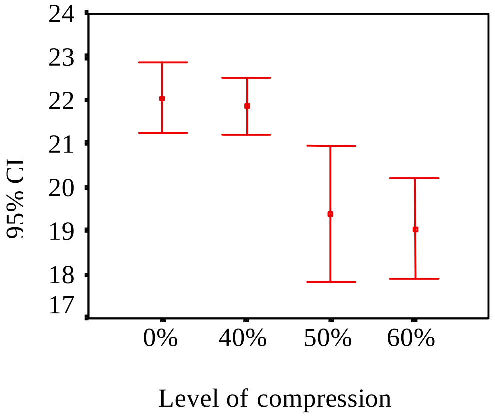
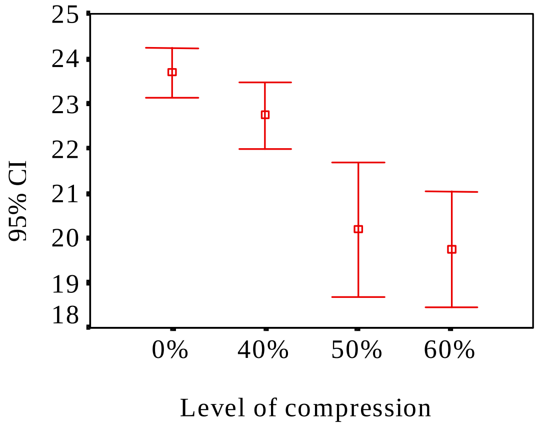


Figure-5: Error graph for 11-11.11 years



Note: CI = Confidence Interval

Thus, for younger children there is no definite trend seen in the scores of time-compressed words. Their might be overlap seen in the score of these children for different compression levels. However, for older children the scores show a definite distinction. This can be attributed to the fact that the auditory perception of younger children might be imperfectly developed (Nagafuchi, 1976). This accounts for the youngest group performing equally poor in 40%, 50% and 60% compressed words.

It can be concluded that while testing children in the age group 7-7.11 years that any of the compression levels can be used, since they performed equally in compressions of 40%, 50%, and 60%. While evaluating children 8-9.11 years, testing with each of the levels of compression may yield different scores. Hence, it is not recommended to substitute one list with the other. However, in the oldest two groups (10 to 11.11 years) either the 50% or the 60% compression lists can be substituted with each other, as they result in similar scores.

In conclusions, analysis of the results obtained from the present study revealed that –

1. There existed no significant difference in right and left ear scores for monotically presented time compressed speech stimuli.

2. There existed no significant difference in the performance of males and females across ages, at different levels of compression.

3. There was a significant difference between the scores of age groups across compression levels within an age group.

  - The 7-7.11 year olds performed equally for 40%, 50% and 60%.
  - The 8-9.11 year olds performed differently for each compression level.
  - The 10-11.11 year olds performed equally for 50% and 60%.

4. There existed significant difference across different levels of compression in each age group. There was decrease in performance seen with increase in the level of compression.

5. While using a time-compressed test as a clinical tool, age appropriate norms should be referred to. Norms for the appropriate levels of compression should also be referred to.

6. When time is a constrain, testing can be done with 0% and 60% compression for all age groups, as distinctly different scores within normal children of this age range are obtained with these two levels of compression. Also in literature, 60% compressed words has been recommended used as a clinical tool for differential diagnosis of different clinical population (Kurdziel et al., 1976, Bornstein & Musiek, 1992). Freeman and Beasley (1978) have stated that the procedure of comparing the discrimination scores obtained at 0% and 60% time compression thus might provide more diagnostic information.

SUMMARY AND CONCLUSION

The purpose of the present study was to develop Time Compressed Speech Test in English and to establish normative data on a group of children with the developed test. The study also aimed at investigating the effect of ear, gender, level of compression and age on the scores of time-compressed words. The task involved identification of monotically presented time compressed monosyllables. The compression levels used in the present study were 0%, 40%, 50% and 60%. The subjects were tested either in the left ear or the right ear.

The subjects taken for the study were 80, normal hearing Indian children in the age range of 7-12 years. All children had English as their medium of instruction for at least one year. None of the subjects had history of any neurological involvement and were initially tested to ensure normal auditory functioning prior to administering the time compressed speech test.

The responses were scored in terms of number of correct responses for different percentages of compression. The raw data was subjected to statistical analysis. Using repeated measure ANOVA, Multivariate test, test of between subject effects, and Duncan’s Post HOC test. The mean, standard deviation and confidence interval were also calculated for different levels of compression across age. The results from the present study supported the findings of previous studies by Beasley et al. (1972a), Nagafuchi (1976), and De Chicchis et al. (1981).

The results revealed that:

1. There existed no significant difference in right and left ear scores for monotically presented time compressed speech stimuli.
2. There existed no significant difference in the performance of males and females across age at different levels of compression.
3. There was a significant difference between the scores of age groups across compression levels within an age group.
    a. The 7-7.11 year olds performed equally for 40%, 50% and 60%.
    b. The 8-9.11 year olds performed differently for each compression level.
    c. The 10-11.11 year olds performed equally for 50% and 60%.
4. The performance of time compressed word decreased with the increase in the level of compression across age.
5. The scores of lesser levels of compression (0%, and 40%) fell in the same subset and that for higher levels of compression (50% and 60%) fell in another subset for all age groups except for 7-7.11 years. In this the children performed equally poor for 40%, 50% and 60% compressed words. This proved that the auditory perception of younger children might be imperfectly developed.
6. While using a time-compressed test as a clinical tool, age appropriate norms should be referred to. Norms for the appropriate levels of compression should also be referred to.

7. When time is a constrain, testing can be done with 0% and 60% compression for all age groups, as distinctly different scores within normal children of this age range are obtained with these two levels of compression. Also in literature, 60% compressed words has been recommended used as a clinical tool for differential diagnosis of different clinical population (Kurdziel et al., 1976, Bornstein & Musiek, 1992). Freeman and Beasley (1978) have stated that the procedure of comparing the discrimination scores obtained at 0% and 60% time compression thus might provide more diagnostic information.

In conclusion, the findings of the present study on the Indian population are consistent with the findings obtained on the Western population. Thus, a similar trend is seen in the performance of normals on time compressed speech test across population. The present study hence revealed that the time compressed speech test can be administered in any ear and in both males and females without adversely affecting the results.

Future Implications:

Time compressed speech test can be used in the identification of potential cortical lesions (temporal lobe lesions). Hence, the time compressed speech test can be incorporated as a part of the Central Auditory Nervous System evaluation battery, to evaluate the central auditory processing. Further utilization of this test will better our understanding of the central auditory nervous system in the elderly population and in the disordered population.

Results of this test would also provide clinician guidelines regarding the measures that need to be taken while providing client rehabilitation. Clients with deviant time compression scores could be provided a temporal based rehabilitation program. Further, the test could be used to monitor progress of therapy.

The developed test could be used for further research. For example the developed test could be used to (a) develop norms for adults and (b) check the effect of temporal based training on time compressed scores.

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