Time compressed speech test in Kannada for children: 7-12 years

Reg. No.A0490005

% A dissertation submitted in part fulfillment of the Masters Degree (Audiology),

University of Mysore, Mysore

All India Institute Of Speech and Hearing
Naimisham Campus
Manasagangothri, Mysore-570006
April, 2006

Dedicated To

Parents & Teachers

..Who makes my dream come true!!!

CERTIFICATE

This is to certify that this master's dissertation entitled **"Time compressed speech test in Kannada for children: 7-12 years"** is the bonafide work done in part fulfillment for the degree of Master of Science (Audiology) of the student with Reg. No.: A0490005. 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.

Prof. M. Jayaram
Director,
All India Institute of Speech & Hearing,
Naimisham Campus,
Mysore-5 70006.

Place: Mysore

April 2006

CERTIFICATE

This is to certify that this master's dissertation entitled **"Time compressed speech test in Kannada 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.

Prof. Asha Yathiraj,

Guide,
Professor of Audiology
All India Institute of Speech & Hearing,
Naimisham Campus,
Manasagangothri, Mysore-5 70006.

Place: Mysore

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DECLARATION

This Master's Dissertation entitled **"Time compressed speech test in Kannada for children: 7-12 years",** is the result of my own study under the guidance of **Prof. Asha Yathiraj,** Department 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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INTRODUCTION

Speech is a complex process. The ability to attend to spoken conversation, to comprehend, remembers, and respond appropriately involves a series of intricate process that occurs automatically in most individuals. Rarely does one consider the complex succession of events that is involved in the integration of information in our brain during conversation. The anatomical network and redundancies of the auditory neural pathways work as an intricate mechanism to perform these functions (Deconde, 1984). Central auditory processing (CAP) is the label ascribed to this neurological phenomenon. This term is used interchangeably with other terminology such as central auditory ability, central auditory perception and central auditory function (Hull & Dilka, 1984).

Auditory processing is required for communication. Central auditory processing involves various processes such as auditory closure (decoding), binaural integration, binaural separation, temporal patterning, binaural interaction, neuromaturation and interhemispheric transfer (Bellis, 1996). Central auditory system mechanism and processes affect non-verbal as well as verbal signals and influence various higher functions including language and learning (Phillips, 1993, 1995; ASHA, 1996).

Central auditory processing disorders (CAPD) may be broadly defined as an impaired ability to discriminate, identify or otherwise process auditory information that cannot be attributed to impaired hearing sensitivity or impaired intellectual function

(Keith & Jerger, 1991). CAPD may also co-exist with a more global dysfunction that affects performance across modalities (ASHA, 1996).

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

The assessment of central auditory processing must begin 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. APD is characterized by poor speech understanding despite normal hearing. In addition, an APD is auditory-specific, so auditory processing capabilities show discrepancies with processing capabilities in other modalities (Jerger & Musiek, 2000).

Various aetiological bases have been described for APDs. Jerger (1998) named three groups of APDs based on the aetiology and symptoms. These three groups were: (1) Lesions of the central auditory system; (2) Inability to hear well in difficult listening situations; and (3) Age-related changes in the central auditory system rather than peripherally. Baran (1996) described eight possible aetiological bases for auditory processing problems: (1) subtle, sub-clinical compromise of the peripheral hearing mechanism not detected by routine peripheral hearing assessment; (2) auditory deficits related to neurological compromise; (3) auditory deficits related to more subtle cerebral morphological abnormalities; (4) auditory deficits related to normal degenerative processes (ageing); (5) cognitive deficits; (6) psychological/ emotional deficits; (7) language differences; (8) and, change in acoustical environment.

In the past, many APD tests have been developed. Subjects with an APDs form a very heterogeneous group. Therefore, they need to be tested with a battery of tests and search for subgroups. One way to approach scoring patterns is to develop auditory sub-profiles. Katz and Smith (1991) defined three major groups of APDs based on their performance, namely auditory decoding, auditory tolerance-fading memory and auditory integration. Bellis and Ferre (1999) and Bellis (1999) added two more to these three subgroups. Thus, five different sub-profiles of APDs were described (three primary and two secondary), along with their underlying neurophysiological region of dysfunction in the brain, as well as their higher-level language and learning implications and sequelae. These profiles were intended to facilitate the interpretation and remediation of APDs.

To evaluate different processes, specific tests have been developed. To evaluate temporal processing, the tests developed are Frequency patterns or Pitch pattern sequence test (PPST) by Pinheiro and Ptacek (1971); Duration pattern test (DPT) by Pinheiro and Musiek (1985); the Gap detection test (GDT) by Keith (2000); and Time-compressed speech test by Beasley, Schwimmer, and Rintelmann (1972). The use of time-altered speech materials has gained recognition as a simple, sensitive and valid clinical tool. Calearo and Lazzaroni, (1957) employed accelerated sentences and describe abnormal time-intensity functions in aged patients and those with temporal lobe lesions. Time-compressed speech has been employed in investigations of central auditory abilities in children with normal peripheral hearing (Beasley, Maki, & Orchik, 1976), normal-hearing adults (Beasley, Schwinner, & Rintelmann, 1972) and adults with sensori-neural hearing loss (Sticht & Gray, 1969; Kurdziel, Rintelmann, & Beasley, 1975). In addition, it has been used to assess auditory processing in adults with temporal lobe lesions (Kurdziel, Noffsinger, & Olsen, 1976), aphasics (Orchik, Walker, & Larson, 1977) and the elderly (Konkle, Beasley, & Bess, 1977).

In the pediatric population, research accelerated in the 1980s. Several tests have been developed for children to help identify the auditory system is functionally normally (Keith & Jerger, 1991). More commonly, central auditory testing in children is used to determine the functional auditory ability.

Need **for** the Study

In literature, there are many studies demonstrating that children with learning disability (LD) may have other associated problems (Larson, Rogers, & Sowell, 1976; Krans & McGee, 1994). Hence, there is a need to detect these problems. It has been found that the test that was developed in the west cannot be directly used in India due to variation in accent. Hence, there is a need to develop tests appropriate for the Indian context, In India, it has been found that dyslexia ranges from 3% (Ramaa, 1985) to 7.5% (Nishi Mary, 1988, cited in Ramaa, 2000).

The monaural low redundancy speech tests available to evaluate children in India are the Speech-In-Noise (SPIN) test and time-compressed speech perception test in English (Sujitha, 2005). Although the SPIN test has been shown to be at least marginally sensitive to a wide variety of disorders of the central auditory nervous system and related disorders (Chermak, Vonhof, & Bendel, 1989; Olsen, Noffsinger, & Kurdziel, 1975), lack of standardized test tools and material-specific normative data have resulted in conflicting finding and questionable test reliability. Therefore, Mueller and Bright (1994) have suggested that SPIN tests may well be the most misused test of central auditory function. The SPIN test is found to have a low sensitivity to brainstem and cortical lesions.

The time-compressed speech perception test, is one test used for central auditory dysfunction evaluation. For the western population, norms for this test has been reported by Beasley, Schwimmer, and Rintelmann, (1972a) and Beasely, Forman, and Rintelmann, (1972b). In India, norms for this test was developed in English for Indian children by Sujitha (2005). No such study has been developed in Indian languages. Therefore, the present study has been taken up to develop and establish normative data for a time-compressed test in Kannada. This will help in the diagnosis of children with auditory perceptual problems, in children who speak this language.

The average intelligibility scores, as measured by time-compressed monosyllables have been found to increase as a function of age in normal children (Beasley, Maki, & Orchik, 1976; Nagafuchi, 1976). However, no significant difference has been found between males and females (Nagafuchi, 1976). There is a need to confirm these findings, and check whether there exists an increase in auditory capacity in normal children as a function of age.

<u>Aim of the Study</u>

The present study had the following aims:

- Develop a time-compressed speech perception test in Kannada, for native speaker of the language.
- Investigate if there is any ear effect on the scores of time-compressed words.
- Investigate if the scores are different across gender.
- Investigate if the scores are different across different ages. If the scores differ across age groups, develop norms for the different age groups, across different levels of compression.
- Investigate if the level of compression affects the scores obtained.
- Investigate the difference in the norms in English and Kannada in the Indian population.

There are several tests on temporal aspects that can be used for the assessment of APDs. It is important to know how sensitive the tests are in detecting the presence of a temporal processing problem. In the following chapter, a detailed review is provided regarding the different temporal based tests used to evaluate individuals with an auditory processing problem.

REVIEW OF THE LITERATURE

Myklebust (1954) was one of the first to suggest that " central hearing loss" contributed to children's language learning deficits. The term central auditory processing disorder (CAPD) has been used to describe functional impairment of the auditory system with respect to different skills. Central auditory processing (CAP) problems may underlie or interact with other difficulties including speech language impairment, attention disorder, learning disability or developmental disabilities (Tallal & Piercy, 1974; Willeford, 1980; Jerger, Martin, & Jerger, 1987). CAP is a dynamic, interactive process in which both bottom up (stimulus driven) and top down (concept driven) mechanisms are activated, depending up on the constraints of the listening event.

Many children, having this problem, struggle academically, often resulting in poor self-esteem, even with professional help. In addition, there are adults who somehow have been able to get through school, but who experience listening difficulties that may affect the quality of their work or, even jeopardize their employment. Recently teachers, parents and even adult consumers themselves have become increasingly aware of auditory processing disorders.

The audiologist can enhance the quality of life of these individuals especially in their academic performance. Children normally need 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 also for long durations. As results, children with an auditory processing problem have considerable problems in a school set-up.

Thus, there is a need to identify these children.

Diagnosis of auditory processing disorders

Auditory processing disorders (APDs) are characterized by poor speech understanding despite normal hearing. 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 of these tests is designed to evaluate various behavioural processes required to process auditory information. Though information can be obtained as early as 5.5 to 6.5 years of age, the administration of the comprehensive central auditory pathway test battery is not performed until the age of 6.5 to 7 years or later to minimize any bias introduced by limited vocabulary and / or attention, hi 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, determines 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 an APD will encounter difficulty when the auditory system is stressed by signal distortion and competing messages (Keith, 1995).

No single test of APD can be expected to challenge the variety of functions required by the central auditory nervous system (CANS) in different listening situations. Therefore, it is necessary to use a test battery approach (Dempsey, 1983). Using a test battery approach, audiologist can determine if CAPD is present and, if so, the specific nature of these difficulties as well as the likely ramifications. They can then use this information to provide individualized management strategies as well as measure the success of interventions by post testing.

Tests of central auditory function have been categorized in a variety of ways. Baran and Musiek (1991) categorize behavioral central tests in the following sub-categories: Dichotic speech tests, temporal ordering tests, monaural low redundancy speech tests and binaural interaction tests. They opined that children being assessed for APD would not necessarily be given a test from each of these categories. Rather, the audiologist would select a battery of tests would 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). Due to the richness of the neural pathways in the 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 test represents a group of tests to evaluate APD. Time compressed speech test is one such test, originally designed by Beasley, Schwimmer, and Rintelmann, (1972) to evaluate monaural low redundancy. Time-compressed speech is generally described in terms of the percentage of temporal reduction, i.e. 30% time compressed speech is speech in which 30% of the signal has been removed in small units (Muller & Bright, 1994). The test evaluates temporal processing which is critical to the perception of speech and music.

Temporal ordering tests form another group of temporal based tests used to evaluate individuals having an APD. Temporal ordering tasks require the listener to make discrimination based on the temporal order or, sequence of auditory stimuli. Primarily, non-speech stimuli such as tones or clicks are utilized in the evaluation of temporal ordering abilities. There is three tests of temporal ordering used clinically: Frequency patterns or Pitch pattern sequence test (PPST) by Pinheiro & Ptacek (1971); Duration pattern test (DPT) by Pinheiro & Musiek (1985); and the Gap detection test (GDT) by Keith (2000).

Time-compressed speech test as a measure of APD

History of the development of time compressed speech test: -

One way to reduce the redundendancy of a speech signal is to alter the temporal characterictistics of the signal. Speech can be temporally altered in a variety of ways. The speaker can simply talk faster or recorded materials 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) 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 (1953, a, 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 cumbersome and inefficient.

The chop-splice method was laborious and time-consuming and hence, has been replaced by more efficient and technically advanced procedures for achieving the same general time-compressed effect.

An electro-mechanical time compressor or expander was developed by Fairbanks, Everett, and Jaeger (1954) in order to overcome the problems associated with both the fast / slow playback and chop-splice techniques. 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 electro-mechanically "spliced" back together, such that the end procedure was a recorded version of the original recording, which was to some specific percentage shorter (compressed) or longer (expanded) than the original. The Springer Information Rate Changer was an electro-mechanical device similar to Fairbanks, device except that the discarded interval had a limited range of variability.

The Lee (1972) Varispeech device, a modification of the Fairbanks, instrument contained 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 with as well as between linguistic sections. Beasley and Freeman (1977) reported of the use of software that could compress or expand the speech signal. Currently there are several such software that are available.

Development of Time-compressed speech for clinical purposes: -

In the evaluation of central auditory dysfunction, the use of time-compressed speech has gained recognition as a simple, sensitive and valid clinical tool. Time-compressed /expanded speech has been used to detect subtle neurological lesions that may go unnoticed by use of standard pure tone and word identification measure of audition. These tests are based upon the subtlety and bottle-neck principle (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) and Dequiros (1964) recognized this problem and consequently employed time-compressed speech signals as a measure for evaluating lesions in the central auditory nervous system. They 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. Temporal alteration of speech stimuli in the form of time compression reduces the extrinsic temporal redundancy of the speech signal (Calearo & Lazzaroni, 1957; Beasley & Maki, 1976), thereby increasing the processing load on the temporal aspect of the auditory perceptual processor (Efron, 1963; Aaronson, 1967; DiSimoni, 1974).

Effect of aging on time-compressed speech scores

Beasley, Maki, and Orchik (1976) were the first to report the clinical use of time-compressed speech with children. Normative data were provided for young children using two measures of speech discrimination, the PBK-50 (Haskins, 1949) and the WIPI (Lerman, Ross, & Me Laughlin, 1965; Ross & Lerman, 1970). Subsequent investigation with the PBK-50 (Manning, Johnston, & Beasley, 1977) indicated reduced performance on a time-compressed speech discrimination task by children displaying auditory perceptual deficits when compared to previously published data with normally hearing children (Beasely, Maki, & Orchik, 1976). The data suggested that measures employing time-compressed speech might be useful in the study of auditory processing in children exhibiting various speech and language disorders.

Luterman, Welsh, and Melrose (1966) and Sticht and Gray (1969), using time-compressed CID W-22 word lists, revealed differential results for young adult listeners compared to geriatric listeners, and sensorineural hearing-impaired listeners compared to normal listeners. This study showed a gradual decrease in the intelligibility of monosyllables corresponding to progressively greater percentages of time compression over the range of 30% to 60% with a dramatic reduction of intelligibility occurring at 70% time-compression. Similar findings were noted earlier by Zemlin, Daniloff, and Shriner (1968) who found a significant breakdown in intelligibility to occur at 70% time compression using different vowels.

A comparison of speech discrimination scores obtained with the Audited Versions of the NU-6 and the CID W-22 test materials indicated that these two measures yielded different results, particularly at the 30% and 60% levels of time compression. It is also commonly used in clinical application of time-compressed speech (Beasley & Freeman, 1977). The difference between the discrimination scores obtained in this study indicated that the effect of the talker was also a significant variable in a time-altered speech discrimination task.

May, Rastatter, and Simmons (1984) used 30 tape-recorded sentences taken from the Carrow Auditory Visual Abilities Test, which were time-compressed by the Lexicon Varispeech II to 50%. Age related changes in auditory discrimination were investigated using this material. Each sentence offered one or more phonemic contrasts (manner or place of articulation, voicing frequency or some combination). It was found that the 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 young adults (N: 15), but the two older groups were each significantly better than each of the two younger groups. In ontogenetic progression of this auditory processing ability seems to mature in the early part of the second decade of life of the five feature contrast, 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 an 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 variations of stimulus complexity. The goal was to identify a subset of temporally mediated, measures that effectively distinguished 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 measure 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. The findings of age related problems for recognition of time compressed speech independent of attenuation imposed by hearing loss, agreed with their previous report (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 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 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 normal and 10 with hearing loss) and older subjects aged 65-72 years (13 normal and 14 with 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 was notably different 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 supported the notion that the problems of older listeners in recognizing time-compressed speech were 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), compared the responses of 18 Spanish-American War Veterans, aged 79-87 years compressed and expanded PB words with 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 and expansion i.e. 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 detrimental to the subject's performances relative to the unaltered condition. Possibly their contradictory findings were because they used much lesser levels of compression when compared with the other studies.

Studies have found that the identification of time compressed speech in children increases with age. The exact age, up to 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 scores decline with age. This may be because aging imposes a limitation on the ability to process rapid speech segments.

Effect of time-compressed speech scores on the clinical population

There are some indications that the intelligibility of time-compressed words is severely attenuated in elderly persons having a sensorineural hearing loss, in persons with temporal lobe lesions, and in persons with diffuse cerebral pathology (Bocca & Calearo, 1963). Time-compression has been used on different clinical population for diagnostic purposes. These include brain damage, auditory processing disorders, learning disability, and specific language impairment.

Baran et al. (1985) evaluated the performance of twenty-seven subjects with surgically, radiologically or, neurologically confirmed lesions of the central nervous system on time-compressed speech test. The 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. The subjects were administered the NU-6 word list at 60% time-compression. 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 at least 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 the time-compressed speech test might 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 retrocochlear or central auditory lesion. The speech tests used were interrupted speech (7 and 10 interruption/s), time-compressed speech (message compressed to 290 words/min) 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/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).

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 Carrow Auditory Visual Abilities Test). Good readers exhibited a significantly higher overall 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.

Many people with developmental dyslexia have difficulty perceiving stop consonant contrast 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, Cornelisson, and Stein (1997) predicted that perception of such stimuli by listener with dyslexia might be improved by stretching them in time equivalent to speaking slowly. Conversely, their perception of the same stimuli thought to be made even worse by compressing them in time equivalent to speaking quickly. They tested 15-children with dyslexia on their ability to correctly identify 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 concluded 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, time compressed words are found to be highly sensitive in identifying children with dyslexia.

Stollman, Kapteyn, and Slesswijik (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 9-12 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 (SRTn) than their normal peers, who performed almost equally as the adult control group. Time-expansion was shown to have a negligible effect on SRTn 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.

Mentally retarded adolescents and non-retarded children participated in three experiments design to examine differences in language processing efficiency by Merril and Mar (1987). A compressed speech technique was used in experiments 1 and 2, while experiment 3 relied on a sentence-picture verification procedure. The results suggested that retarded and non-retarded individuals differed in their ability to execute the semantic analytic processes but not necessarily the phonological encoding processes that were involved in auditory language comprehension. In addition, the data suggested possible group difference in the quality of the semantic representation encoded during sentence processing.

Kurdziel et al. (1976) administered tape recording of time compressed (40% and 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 had a breakdown of speech discrimination in the ear contralateral to the lesion. Patients with a discrete unilateral cortical lesion generally did not demonstrate breakdown with the 60% time compressed materials.

Orchik et al. (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 Word Intelligibility Picture Identification test, which was time compressed at 0%, 30% and 60%. Difference in discrimination were greatest at 60% time compression, whereas in the aphasic group, the mean discrimination score was poorer than their matched controls by 30 %.

The above research brings to light that the time compressed test is useful in determining the presence of auditory processing problems. The test is able to detect APDs that result as a consequence of different causes, both pathological well as non-pathological. The majority of studies indicate that a compression of 60% is useful in detecting the presence of an APD.

Besides the time-compressed speech test, other tests have been developed to identify the presence of temporal processing problems. One such test, designed to identify temporal sequencing problems is the pitch pattern sequence test.

Pitch Pattern Sequence Test as a measure of APD

The Pitch Pattern Sequence Test (PPST) was introduced by Pinheiro (1976, 1977) to check temporal processing. It is composed of sequence of tones, with each sequence containing three tone bursts, hi each sequence two of the tone bursts are of the same frequency, and one tone is of a different frequency. The test is designed to detect pattern perception as well as temporal sequencing abilities. It provides information regarding neuromaturation in children by indicating the degree of myelination of the corpus callosum. It also helps in identification of lesions at the peripheral, brainstem, and temporal lobe levels. Both procedural as well as subject related factors affect the results of PPST. However, information of laterality or localization of lesion is not obtained from this test.

Studies done by De Fosse and Pinheiro (1978) indicated that musicians perform better than non-musicians on the frequency pattern test. Thus, the test results would vary depending on the exposure a client has had to music.

A comparison of either verbal or manual response with hummed responses is valuable in differentiating impairments in perception from impairments in processing auditory sequences. The sequential stimuli are non-verbal, hence the task is a very easy one for normal adults; and various response methods may be tailored to the ability of the subject to respond (Pinheiro & Musiek, 1985).

Effect of age on Pitch Pattern Sequence Test Scores

PPST can be an appropriate measure for children above the age of 8 years (Bellis, 1996). In PPST, the effect of age on tests of temporal patterning may be inferred from studies of patients with corpus callosal involvement (Musiek, Pinheiro, & Wilson, 1980). Performance on temporal patterning tasks involving linguistic labeling of non-speech stimuli would not be expected to reach adult values until neuromaturation of the neural structures critical to the task, particularly the corpus callosum is complete.

Based on their outstanding work on the developing brain, Yakovlev and Lecours, (1967, cited in Pinheiro & Musiek, 1985) suggested that myelination of the corpus callosum may not be complete until 10 years of age. The optimal function (origination and synchronization with other neural units from various complex analyses) of these neural developments of myelin sheath may take even longer.

The development of temporal processing abilities appears to follow the course of neuromaturation, with skills improving as a function of age until approximately 12 years of age. In addition, the effect of age upon temporal processing depends on the task selected and to some degree, on attentional factors (Bellis, 1996). Normative data was obtained by Bellis (1996). The study indicated that the scores improved till age of 10 years.

Effect of Pitch Pattern Sequence Test scores on the clinical population

The PPST is useful in detection of disorders of the cerebral hemispheres (Pinheiro & Musiek, 1985; Musiek & Pinheiro, 1987). The test has been shown to be sensitive to corpus callosal dysfunction. Patient with disruptions in the interhemispheric transfer of auditory information exhibit improvement in performance when the linguistic labeling component of the test is removed by requesting the listener to hum the pattern rather than verbally describe it (Musiek et al, 1980). Results of the PPST have also provided information regarding neuromaturation in a child with learning disability by indicating the degree of myelination of the corpus callosum (Musiek, Gollegley, & Baran, 1984).

The Pitch Pattern Sequence Test has been found to be sensitive to hemispheric lesions (Pinheiro, 1976) and to auditory processing dysfunctions related to dyslexia (Pinheiro, 1977). This monaurally presented test often showed binaural deficits in people with brain lesions. A better understanding of this 'bilateral phenomena' was achieved with the report on auditory pattern perception in split-brain patients (Musiek, et al. 1980). This study supported the theory that both hemispheres were needed to decode the pattern and report it verbally. This is because the left hemisphere is dominant for speech, language and temporal ordering, where as the right hemisphere recognizes acoustic contours and patterns (Kimura, 1964; Blumstein & Cooper, 1974).

The pitch (frequency) pattern test is valuable for detecting CAPD in children with learning disabilities (Musiek & Geurkink, 1980; Musiek, Geurkink, & Keitel, 1982). An extensive study on patients with cochlear brainstems or, cerebral lesions showed that the PPST was highly sensitive for cerebral involvement and was relatively resistant to mild / moderate cochlear hearing loss (Musiek & Pinheiro, 1987). For brainstem lesions, this test was only moderately sensitive. However, it did not provide laterality information.

Musiek et al. (1980) studied auditory pattern perception in split-brain patients. Three right-handed subjects who had complete sections of the corpus callosum were tested on auditory pattern sequencing tasks. Subjects 1 & 2 were tested approximately 10 days after the surgery while subject 3 was tested prior to his commisurotomy, 10 days after surgery and again 1 year later. All subjects had normal pure tone audiometric thresholds (250 Hz to 8 kHz), normal speech recognition thresholds as well as speech discrimination scores in both ears after the commissurotomy. Pitch patterns consisting of two different frequencies (1122 Hz and 880 Hz) and intensity patterns consisted of soft and loud sounds of 1 kHz tone (differences of 7 dBHL). Thirty frequency and thirty intensity patterns were presented at 40 dBHL above the SRT. The subjects were asked to respond both verbally and humming. Post operatively, all three subjects exhibited great difficulty in verbally sequencing both intensity and pitch patterns presented to either ear.

The right ear verbal performance tended to be poorer than the left ear performance. Subjects 2 & 3 were able to hum the pitch patterns post operatively. Subject 2 performed within the normal range for stimuli presented to both ears while subject 3 scored only slightly below normal in both ears. Results indicated that sectioning the corpus collosum dramatically affects the ability to verbally report for both intensity and frequency patterns. However, the ability of the subjects to correctly hum frequency patterns was not impaired. In this investigation, detailed testing was done both before and after the surgery for comparison. However only 3 subjects were taken.

Cranford, Stream, Rye, and Slade (1982) studied detection versus discrimination of brief duration tones in subjects with temporal lobe damage. Standard audiometric examination involving air conduction, pure tones and speech recognition threshold (SRT) was carried out. Absolute detection threshold and difference limen were found for 1 kHz tones over a range of seven signal durations 500, 200, 100, 50, 20 and 5 msec. The presentation level was 40 dBHL above subject's threshold. A total of 10 subjects with unilateral damage to neocortical substance were tested. Seven subjects sustained damage involving the primary auditory receptive zones (Broadman's areas 41 & 42) in the anterior and posterior transverse temporal gyri or Heschl's convolutions, whereas 3 subjects had unilateral damage confined to areas outside the parieto-temporal region. Results indicated a similar behavioural dissociation for the seven subjects with a temporal lobe damage in the brief tone tests. All subjects exhibited normal detection threshold in conjunction with substantially elevated frequency difference limen. A comparison was made with a normal group but it is possible that the subject's physical motor involvement might have affected the client's responses.

Tallal (1980) observed that there were no significant differences between scores of twenty reading disabled and four normal children in which stimuli were presented at slower rates. However, when the stimuli were presented more rapidly, the reading impaired group made significantly more error than the controls. All subjects performances were virtually errorless on the same-different discrimination test when the two tones to be discriminated were separated by relatively long intervals. The reading impaired children's ability to use phonics skill (non-sense word reading) was also examined. There was a high correlation between the number of errors made on the phonics-reading test and the number of errors made in responding to the rapidly present stimuli in the auditory perceptual tests. This study supports the hypothesis that some reading impairments are related to two level auditory perceptual dysfunction that affects the ability to learn to use phonic skills adequately.

Lowe and Campbell (1965) investigated the ability of eight normal and eight aphasoid children to perform tasks involving judgments of succession and order. Stimulus used was pure tone. Subjects matched according to age, were from 7 to 14 years of age. Some aphasoid subjects had possible minimal hearing losses. Each child was presented the succession task first, then the ordering task. All pulses were presented at 50 dB above thresholds established prior to the experiment on normal adults. The time between pulse onsets was varied to determine the minimum time separation necessary for both the tasks; a subject's score was the time separation at the 75% level of accuracy with a two alternative forced choice paradigm. Results showed no statistically significant difference between the aphasoid and normal children on the succession task. Although, some degree of peripheral hearing loss may have existed in the aphasoid group, this result indicated that the effects of such losses were minimal. The order task yielded a significant difference between the two groups at the 0.05 levels. While this study appears to have diagnostic, therapeutic and theoretical value, the results are of limited value since only a few subjects were taken.

Musiek et al. (1984) investigated myelination of the corpus callosum and auditory processing problems in children. Central auditory test results from four individuals cases as well as mean data from a group of sixteen children with a learning disability have been highlighted. Their selected children demonstrate the auditory disconnection profile (ADP). The ADP requires normal performance on low-redundancy monotic speech tests, such as low pass filter's test, marked left ear deficits for dichotic speech tasks and bilaterally poor performance on the pitch pattern sequence test by verbal report but also the ability to hum patterns correctly. This profile is commonly observed in adult split-brain subjects and implicates the corpus callosum as the anatomical site of dysfunction.

From the above literatures, it can be concluded that PPST is able to detect the APDs that result as consequence of different causes, both pathological as well as non-pathological. The majority of studies indicate that this temporal ordering or patterning test is sensitive to cerebral lesions but does not provide lateralization information.

Duration Pattern Test (DPT) as **a measure of APD**

Pinheiro and Musiek (1985) developed the DPT, which was similar to the PPST except that the frequency of the tones was held constant at 1 kHz and the duration was the factor that had to be discriminated. The DPT assessed the processes of duration discrimination, temporal ordering and linguistic labeling. The DPT is a test for temporal ordering or temporal patterning. Temporal patterning involves discrimination of difference in auditory stimuli, sequencing of auditory stimuli, gestalt pattern perception and trace memory (Musiek & Chermak, 1995). Musiek, Baran, and Pinheiro (1990) reported that this test is highly sensitive to cerebral lesions (86%) and also has relatively high specificity rating. Test-retest data on DPT have been shown to be reasonably good (Humes, Coughlin, & Talley, 1997).

DPT assesses integration across processing regions in the right hemisphere, which is responsible for suprasegmental information, and spoken language perception that enables the processing of linguistic content, such as lexicon, semantic relations and syntax (Musiek & Lamb, 1994).

Effect of age on Duration Pattern Test Score

Hall and Grose (1994) found that the peripheral mechanism responsible for encoding temporal aspects of the acoustic signal appeared to be well developed in young listeners. However, the ability of the CANS to extract and process temporal cues appeared to improve as a function of age. Performance on temporal patterning tasks, which involves linguistic labeling of non-speech stimuli cannot be expected to reach adults form until neuromaturatiton of the neural structures, critical to the task, particularly the corpus callosum is complete. Adult values of DPT are not attained until 11 to 12 years of age. Thus, the development of temporal processing abilities appears to follow the course of neuromaturation with skills improving as a function of age, until approximately 12 years of age.

Effect of Duration Pattern Test scores on the clinical population

Divenyi and Robinson (1989) concluded that the duration parameter was critical to the ordering of acoustic stimuli in the paradigm they used with aphasic patients. The finding of bilateral deficits associated with unilateral lesions indicates that the duration pattern test cannot provide definitive laterality information. It can be used to assess children and individuals with limited or impaired language skills. It generally requires less time and easy scoring.

Theoretically and some experiments support the concept that both the hemispheres must interact to decode the pattern and orally report it (Musiek et al. 1980, 1984). Humming the patterns appears to requires only the right hemisphere, hence if a subject cannot orally report the patterns, but hum them could mean that the right hemisphere is intact and the problem is either in the left hemisphere or, the corpus callosum (Musiek et al. 1980; Musiek et al. 1984).

Thompson and Abel (1992) reported that listeners with lesions of the left temporal lobe tended to demonstrate greater performance deficits. Inter-hemispheric corpus callosum lesions resulted in bilateral deficits on tests of temporal patterning, i.e., on DPT, when the listener was required to respond verbally. Bilateral deficits on DPT for verbal responses have been reported for patients with deep brain lesions, presumably affecting the transcortical auditory pathway (Musiek et al., 1990). Split-brain patients typically demonstrated bilateral (for verbal report) on pattern perception tests, even though the assessment is a monaural procedure.

Musiek and Lamb (1994) used the terms cortical and hemispheric to differentiate between the two types of cerebral lesion. Cortical refers to the gray matter of the brain alone where as hemispheric refers to lesions that affect both the white and gray matter. With similar performance in both the ears, many audiologists opt for doing the test in a sound field.

It can be inferred from the studies on DPT, that scores on the test varies as a functions of age. This is similar to other tests such as time-compression and PPST, which are also influenced by age. The test has been found in evaluating cerebral lesions. The scores on the test varied depending on the response mode used.

Gap Detection Test (GDT) as a measure of APD

Williams and Perrott (1972) introduced gap detection *testing-.,Gap* detection is a hearing test that measures the ability to resolve differences in time. In this test, three noise bursts are heared, with one of them having a silent interval ("gap") in it. The listener has to select the one with the gap by pointing and clicking a mouse button to the corresponding light. The listener should guess even if he/she is not sure and continue until the program stops. Depending on the response, the gap may become longer or shorter or totally undetectable.

The computer program automatically tracks the responses and calculates the smallest gap that can be detected.

The Gap Detection Test (GDT) is one of the psychophysical methods to measure a listener's ability to detect a brief temporal gap separating two successive stimuli. It is probably the most commonly used measure of temporal resolution i.e., ability to follow rapid changes over time. Gap detection provides a description of temporal resolution based on a single threshold, where as other methods requires multiple threshold estimates. Another advantage is that the gap detection is easy to measure in naive listeners, including infants. The gap detection thresholds obtained from naive listeners are close to those obtained from well-trained listeners (Werner, Marean, Halpen, Spetners, & Gillenwater, 1992).

Gap stimuli used in psychoacoustics studies are acoustically analogous to voice-onset-time for consonants in speech (or formants) and it is necessary for linguistic ability during developmental ages (Strouse, Ashmead, Ohde, & Grantham, 1998).

Effect of age on Gap Detection Test Score

It is generally acknowledged that auditory temporal processing improves substantially over the first several years of life. However, there is considerable disagreement about the specific developmental timetable. For example, the age of achievements of adult-like temporal activity is reported to be between 5 to 6 years of age by some investigators (Morrongiello, Knlipg, & Clifton, 1984; Jansen & Neff, 1993), 9 and 11 years of age by others (Davis & Mc Croskey, 1980, cited in Sandra, Bruce, & Joanna, 1995).

Werner et al. (1992) found that the gap thresholds in 3, 6 and 12 months old infants were approximately 60 msec in contrast to gap thresholds of approximately 5 msec in adults. There was a little difference among infants of different ages, although variability was high among 12 month olds and some of these had gap thresholds that were close to adult values. The results in (Irwin et al. 1985, cited in Formby & Forrest, 1991) disagree on the age at which gap threshold mature. Irwin found that gap threshold was not mature, until 10 to 12 years, where as Wightman obtained adult-like gap threshold among 5 to 7 year old. Schneider, Pichora-Fuller, Kowalchule, and Lamb (1994) reported that gap thresholds of elderly subjects were more variable and about twice as large as those from young subjects in all conditions studied, i.e., older subjects have poorer temporal resolution.

In a large-scale study, Lutman (1991) found that gap detection threshold deteriorated with hearing loss but not with age for three groups of subjects aged 50-59, 60-69, and 70-79 years. However, using a related paradigm, Fitzgibbon and Gordon-Salant (1995) measured difference limen for gaps from both young and aged subjects with or without hearing loss, and reported that elderly listeners performed more poorly than young listeners did and that hearing loss had no systematic effect on gap detection. Thus, the effect of the subjects age on gap detection ability are not clear.

Psychophysical evidence indicates that trained normal hearing observers can discriminate fluctuations in a waveform that occurs in time intervals as brief as 2-3 ms. Resolution thresholds in this range come from several studies that were designed to measure auditory temporal acuity (Miller & Taylor, 1948; Plomp 1964; & Green, 1973). Forrest and Green (1987) have reported that gap detection and the temporal modulation transfer function yield similar estimates of temporal acuity.

Effect of Gap Detection Test scores on the clinical population

Study of temporal resolution in ears with sensori-neural impairment has not been pursued extensively. Cudahy and Elliott (1975, cited in He, Horwitz, Dubno, & Mills., 1999) inferred from data that some listeners with sensorineural impairment have reduced temporal resolving capacity. Cudahy (1977, cited in He et al., 1999) also reported cases of elevated gap threshold in subjects with a high frequency hearing loss. The gap threshold of the hearing impaired subjects were significantly greater than those of normal hearing subjects. This condition held whether the comparison to normal resolution was made for signals of equivalent SPL or equivalent SL and at each octave band frequencies.

Individuals with developmental language disabilities, including developmental dyslexia and specific language impairment (SLI) exhibit impairments in processing rapidly presented auditory stimuli. Central processing is important in temporal resolution and specifically in gap detection. A lesion of the auditory cortex has been shown to produce deficits in gap detection in rats & ferrets, animals whose temporal resolution is similar to that of humans (Ison, O'Connor, Bowen, & Bocirnea, 1991; Kelly & Rooney, 1996). Further, Shannon, and Otto (1990) have reported that gap detection in people with auditory brainstem implant was about the same as, or, perhaps a little worse than that of people with normal hearing or with cochlear implant.

Tallal and Piercy (1974) demonstrated that normal children were able to discriminate two 75 msec tones separated by an inter stimulus interval (ISI) as short as 8 msec, while individuals with SLI required an ISI exceeding 300 msec to perform the same discrimination at the same level of accuracy. Similar rate-specific auditory processing deficits have been observed in dyslexics behaviour and neurophysiology, using both speech and non-speech stimuli.

These accumulated findings overwhelmingly support the view that individuals with developmental language disabilities have a fundamental dysfunction in the ability to process brief auditory stimulus followed in rapid succession by other acoustic information (i.e., rapid auditory processing).

Two main effects can be observed regarding temporal processing in hearing-impaired listener: -

1) It appears that for normal listeners, the signal level has an important influence on temporal resolution. This necessarily implies the existence of an inverse relationship between degree of hearing loss and the optimum temporal resolution that can be accepted

with stimulation held constant in terms of SPL. The characteristics of such a relationship may vary with stimulus frequency band.

2) The influence of signal frequency content on subjects performance suggests that the configuration of hearing loss may be a determining factor of temporal resolution in other hearing impaired listeners, i.e. the maturity of cochlear-impaired listener shows greater sensitivity losses at the higher audiometric test frequencies. These same frequency regions may prove to be dominant for temporal resolution. This is an outcome which, if confirmed would impact a relative disadvantage (re: optimal normal acuity) in temporal processing to these listeners.

Several groups of workers have reported that the threshold for the detection of temporal gaps in noise stimuli are usually larger for subjects with cochlear hearing impairments than for normally hearing subjects. This is true both for broad band noise stimuli (Irwin, Hinchicliff, & Klump, 1981; Florentine & Buus, 1984) and for band pass noise stimuli presented in a broad band or band stop background (Fitzgibbons & Wightmann, 1982; Buss & Florentine, 1985).

For broad band stimuli, it appears that subjects primarily use information from the highest frequency region available (Shailer & Moore, 1983, 1985). For subjects with high frequency hearing loss, performance might be poorer simply because the higher frequency component in the stimuli are inaudible (Bacon & Viemeister, 1985a, cited in Bacon, Glasberg, & Moore, 1987).

Studies on gap detection threshold bring to light that this is one of the few tests to detect APD, that can be administered on clients with a peripheral hearing loss. This test provides information on temporal resolution in clients with sensorineural hearing loss as well as clients with a central problem. There, however is a lack of concensus regarding the maturation of gap detection in children.

The overall review of literature shows that there are several variables that can be considered during administering the APD test battery even in temporal aspects. It is evident from the literature that a time compressed speech perception test provides information about auditory closure and is sensitive to the cortical and sub-cortical regions. However, Pitch Pattern Sequence Test and Duration Pattern Test are more sensitive to cerebral lesions and information about temporal ordering or sequencing. Gap Detection Test gives information about the temporal resolution or acuity. Therefore, there is a need to apply test battery according to the site of lesion or processing which is affected. There is a need to develop the test in different language for the utility of the test in diagnosing auditory processing problems.

METHOD

The present study aimed at developing a time-compressed speech test in Kannada for Kannada speaking children. The study also aimed at obtaining norms for children in different age groups using the test with four compression levels (0%, 40%, 50% and 60%).

Subjects

The subjects for the study were a group a group of 60 normal children (30 boys and 30 girls) in the age range of 7 years to 12 years. These subjects were divided in to five age groups (7 years to 7 years 11 months, 8 years to 8 years 11 months, 9 years to 9 years 11 months, 10 years to 10 years 11 months, and 11 years to 11 years 11 months). Each group had 6 boys and 6 girls.

Subject selection criteria

Subjects who fulfilled the below mentioned criteria were included in the study: -

> They should be native, fluent Kannada speakers.

> They should have normal I.Q.

> They should not have any history of otological or neurological problems.

> Their pure tone thresholds should be normal.

> They should not have any history of hearing impairment and /or speech disorders.

> Their speech identification scores should be more than or equal to 90%.

> They should not have any report of poor academic performance.

> The subjects should not have any illness on the day of evaluation.

> They should not have any auditory processing disorders, which was determined using the screening checklist for auditory processing (SCAP), which was developed by Yathiraj and Mascarenhas (2003).

Development of the test

The stimuli from the "Bisyllabic Phonemically Balanced Words in Kannada for Children" developed by Yathiraj and Vijyalakshmi (2005) was used to prepare the compressed material. This test consisted of four lists with each list having 25 Kannada bisyllabic words which were phonemically balanced. The lists were reported to be equal in terms of phonemic balance as well as perceptual difficulty. The CD recorded version of the test was used. The lists had been recorded in a Pentium IV computer by a female speaker who was a native speaker of Kannada using the Creative Wave Studio software. These lists were compressed using the Praat software. Four compression levels were used i.e. 0%, 40%, 50%, and 60%. List 1 was compressed to 0%, list 2 to 40%, list 3 to 50%, and list 4 to 60%. A 1 kHz calibration tone was recorded before each list for adjusting the VU meter of the audiometer. The output of the computer was recorded onto an audio CD (CDR 700 MB) using the Easy CD Creator software. The HP CD-writer +8200 series was used to write the material onto the CD.

Instrumentation

A Pentium IV computer with the Praat software was used for preparing the compressed speech material. A two channel clinical audiometer Madsen OB 922 was used for the preliminary test as well as for presenting the time compressed signal. It was coupled to a TDH-39 earphone housed in MX-41 /AR ear cushions, for air conduction testing. Bone conduction testing was done using radio ear B- 71 BC vibrator. The audiometer was calibrated according to ANSI standards (1991).

For presenting the time compressed test signal, an audio CD was played on a CD player (Philips AZ 2160 V audio/ video CD), the output of which was routed to the tape input of the clinical audiometer, Madsen OB 922. The output of the audiometer was presented through TDH-39 earphones housed in MX- 41 /AR ear cushions. An immitance audiometer, GSI Tympstar was used for ruling out middle ear pathology.

Test Environment

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

Procedure

I. *Procedure for subject selection*

The SCAP was administered on children from primary and middle schools in Mysore city, who had Kannada as their medium of instruction. This was done to avoid including children with an auditory processing problem. The questionnaire was answered by teachers who knew the children well. Those who passed the checklist and met the subject selection criteria were included in the study. The children were taken from five different government and private schools having different socio-economic backgrounds.

Pure tone air conduction and bone conduction threshold were obtained using a modified Hudson-Westlake procedure. Air conduction thresholds were obtained for frequencies 250-8000 Hz and bone conduction threshold were obtained for frequencies 250-4000 Hz. Those subjects with pure tone thresholds within 15 dBHL in the frequency range of 250-8000 Hz in both ears and air bone gap less then 10 dBHL at all frequency (250-4000Hz) were selected. Immitance testing was used to rule out the presence of any middle ear problem. Only those subjects with normal tympanograms and reflex thresholds were evaluated further.

II. *Procedure for obtaining normative data*

The subjects who met all the subject selection criteria were administered the developed time-compressed speech test. The stimuli were played on the CD player, the output of which was routed to the audiometer. The subjects heared the stimuli through headphones. Prior to the presentation of the lists, it was ensured that VU meter of the audiometer deflected to zero, using the 1 kHz calibration tone. The stimulus was presented at 40 dBSL monaurally. Half the subjects were tested in the right ear while the other half was tested in the left ear to avoid an ear effect. The subjects were instructed to repeat what was heard by them. This was scored by a tester who was a native speaker of Kannada. They were told that they could guess the words in case they were not sure of what they heard. Each subject heard all four lists at 0% compression (no compression) as well as at 40 %, 50% and 60% compression. The lists were randomized so that any sequence effect of the compression level did not contaminate the findings.

Scoring

Each correct response was assigned a score of one, while a wrong response was given a score of zero. The scoring was done separate for the different levels of compression. The raw scores were statistically analyzed.

Results and Discussion

hi this section, the results obtained from the present study are discussed. The data obtained was subjected to statistical analysis using the SPSS (version 10.0) software. The analysis was done to obtain information on the following: -

i) Ear effect

ii) Gender effect

iii) Effect of level of compression with reference to age

a) Effect of compression within an age group

b) Effect of compression across ages

The above effects were analyzed using descriptive statistics, as well as a three-way MAN OVA. Post hoc analysis was carried out using the Duncan's test and Bonferroni's multiple comparison tests, when required.

i) **EAR** EFFECT

The mean and standard deviation of the right ear and left ear was determined at each compression level for each age group (Table 1). The MANOVA results indicated that there was no significant difference between the right and the left ear at different compression levels. This finding was seen across all the age groups.

Table 1: - Mean and Standard Deviation (SD) for right and left ears, males and females, across age groups for different levels of compression.

Level of compression	Age	Ear	Mean		S D	
			Male	Female	Male	Female
0%	7-7.11	Right	23.67	24.33	1.15	.58
		Left	23.33	24.00	2.89	1.00
	8-8.11	Right	24.33	22.00	.58	2.00
		Left	24.33	23.67	1.15	.58
	9-9.11	Right	24.33	24.67	.58	.58
		Left	24.33	23.67	1.15	1.15
	10-10.11	Right	24.67	24.33	.58	.58
		Left	24.33	24.00	.58	1.00
	11-11.11	Right	25.00	25.00	.00	.00
		Left	24.67	23.33	.58	1.53
40%	7-7.11	Right	21.67	22.67	2.89	2.31
		Left	22.00	22.33	3.00	2.52
	8-8.11	Right	24.00	23.67	1.00	.58
		Left	23.33	22.33	1.53	.58
	9-9.11	Right	23.00	23.00	1.73	1.73
		Left	23.00	24.00	1.00	1.00
	10-10.11	Right	24.33	24.00	1.15	1.73
		Left	24.00	24.33	.00	1.15
	11 -11.11	Right	25.00	24.00	.00	1.73
		Left	24.33	24.33	.58	1.15
50%	7-7.11	Right	21.67	21.33	2.08	.58
		Left	21.67	21.00	2.08	1.73
	8-8.11	Right	22.67	21.67	.58	2.52
		Left	22.00	21.00	1.00	1.00
	9-9.11	Right	22.33	22.33	.58	2.08
		Left	21.33	21.33	2.31	1.15
	10-10.11	Right	22.67	23.33	2.52	1.15
		Left	22.67	23.67	1.53	1.15
	11 -11.11	Right	24.67	23.33	.58	2.08
		Left	22.67	23.67	2.31	1.15
60%	7-7.11	Right	21.33	22.67	3.06	2.52
		Left	22.67	22.00	2.08	3.00
	8-8.11	Right	23.67	21.67	1.15	.58
		Left	22.33	20.67	2.31	.58
	9-9.11	Right	22.33	23.33	3.06	2.08
		Left	23.33	23.00	.58	.00
	10-10.11	Right	22.33	22.00	2.08	2.00
		Left	22.67	23.33	1.15	.58
	11 -11.11	Right	24.33	24.67	.58	.58
		Left	23.33	22.67	.58	-2.52

The results obtained from the present study are in agreement with the results of a study conducted on the western population by Beasley et al. (1972) and on Indian non-native English speakers by Sujitha (2005). They reported that there existed no difference between the right and left ear scores at different levels of time-compression. Beasley et al. (1972 a) postulated that in order to validly use the same test for both the right and left ears, performance of normal subjects would warrant that test results between ears be essentially equal.

Under a dichotic listening condition, a right ear and left ear superiority was found for speech and non-speech stimuli respectively (Kimura, 1967, cited in Bellis, 1996). This is because dichotic tests check for hemispheric dominance. However, studies of monotic listening tasks (Glorig, 1958, cited in Bellis, 1996; Dirks, 1964) have failed to reveal clinically significant right (dominant) ear effects, as they do not check for hemisphere dominance. Thus, Beasley et al. (1972) suggested that time-compressed speech can be clinically utilized in a monotic listening task without being confounded by ear laterality effects.

Thus, like studies reported in the literature, the results of the present study indicated that there is no significant difference between the two ears for monotically presented time-compressed stimuli. Hence, the norms obtained would hold good for either ear.

iii) EFFECT OF LEVEL OF COMPRESSION WITH REFERENCE TO AGE

a) Effect of compression within an age group

As there was no difference between genders as well as between ears the whole data was combined. Further analysis done with combined information for different compression levels and different ages.

Table 2 :- Mean, SD, Confidence Interval, Maximum and Minimum scores for all age groups at different levels of compression.

AGE		Mean	95% Confidence Interval for Mean		Std. Deviation	Minimum	Maximum
			Lower Bound	Upper Bound			
7-7.11	0%	23.6	22.52	24.68	1.51	20	25
	40%	21.6	20.08	23.12	2.12	19	25
	50%	21.1	20.12	22.08	1.37	19	24
	60%	21.6	20.05	23.15	2.17	18	25
8-8.11	0%	23.6	22.58	24.62	1.43	20	25
	40%	23.4	22.56	24.24	1.17	22	25
	50%	21.7	20.63	22.77	1.49	19	24
	60%	21.8	20.74	22.86	1.48	20	25
9-9.11	0%	24.1	23.47	24.73	.88	23	25
	40%	23.1	22.12	24.08	1.37	21	25
	50%	21.4	20.50	22.30	1.26	20	23
	60%	22.8	21.59	24.01	1.69	19	25
10-10.11	0%	24.2	23.75	24.65	.63	23	25
	40%	24.1	23.31	24.89	1.10	22	25
	50%	23.0	21.83	24.17	1.63	20	25
	60%	22.3	21.29	23.31	1.42	20	24
11-11.11	0%	24.4	23.63	25.17	1.07	22	25
	40%	24.3	23.54	25.06	1.06	22	25
	50%	23.3	22.13	24.47	1.64	20	25
	60%	23.6	22.52	24.68	1.51	20	25

Examination of the raw data indicated that a few subjects showed no change in scores with increase in compression level. Hence, further analysis was done after deleting the scores of these subjects, who continued to perform well inspite of the compression. This was done to avoid the scores skewing the results. Thus, from each age group, the scores of two subjects were dropped and the data was analyzed for 50 subjects. The mean, SD & confidence interval for the 50 subjects is given in Table 2.

From the information in Table 2 and Figures 1 to 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. In order to find out if there was a significant difference for different level of compression in a particular age group, repeated measure ANOVA was done (Table 3). At all the ages, except the oldest age group, there was a significant difference ($p < 0.001$) across the compression levels.

Table 3: - Significance difference for different compression within age groups

Age	F (df) - value	Significance (p-value)
7-7.11	$F(3, 33) = 8.756$	< 0.001
8-8.11	$F(3, 33) = 8.306$	< 0.001
9-9.11	$F(3, 33) = 8.582$	< 0.001
10-10.11	$F(3, 33) = 7.923$	< 0.001
11-11.11	$F(3, 33) = 2.073$	> 0.05 (NS)

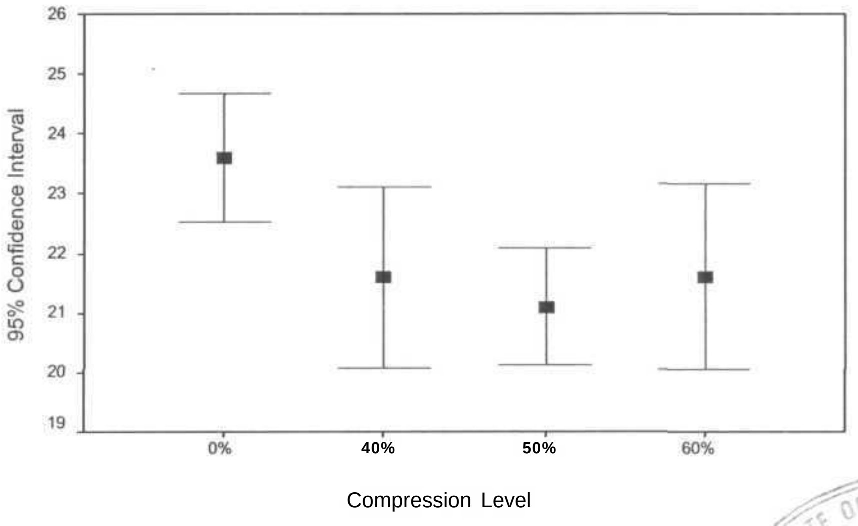
To check whether this significant difference was present across all compression levels for each age group, the Boneferroni multiple comparisons test was done to see the pair-wise differences. The level of significance for the different pairs is given in Table 4.

Table 4: - Significance difference between different compression levels across different age groups.

Tested pair	7-7.11	8-8.11	9-9.11	10-10.11
0% & 40%	<0.05	NS	NS	NS
0% & 50%	< 0.001	<0.05	<0.01	NS
0% & 60%	NS	NS	NS	<0.05

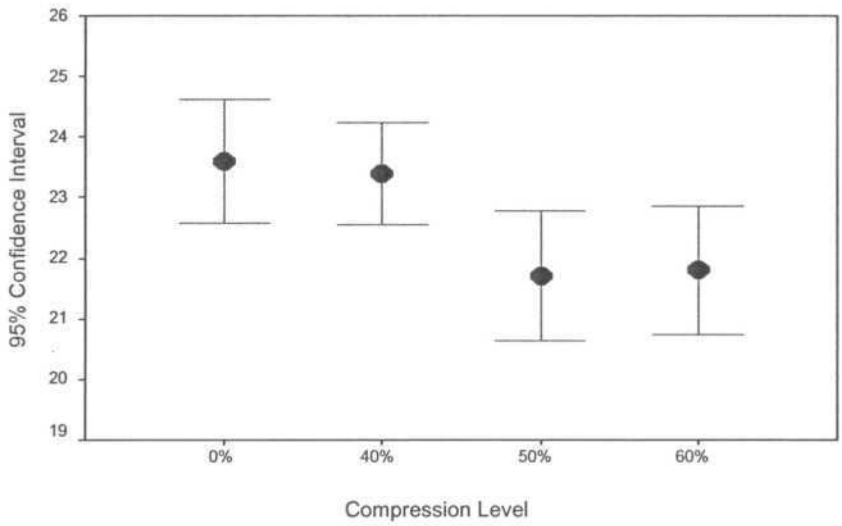
The children in the age range 7-7.11 year showed an overlap in the scores for compression of 40%, 50% and 60% while their performance at the 0% compression was different (Figure 1). Their scores obtained at 0% compression differed significantly from the scores obtained at 40% and 50%, but it did not differ from the 60% scores (Table 4).

Fig. 1: Error bar for 7 -7.11 years



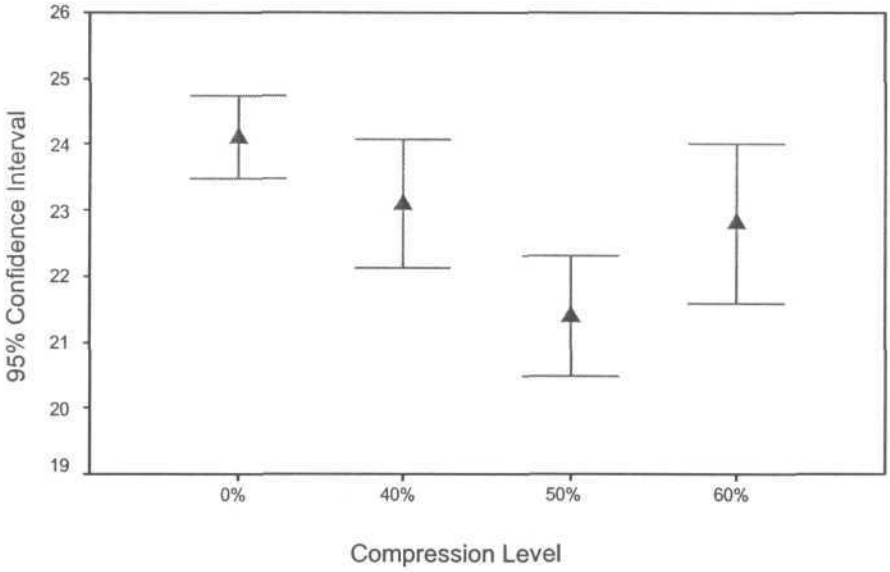
From Table 4 and in Figure 2, it is evident that for the 8-8.11 year olds, the 0% compression level was not different from the 40% compression level but it was different from 50% and 60% compression levels.

Fig. 2: Error bar for 8 - 8.11 years



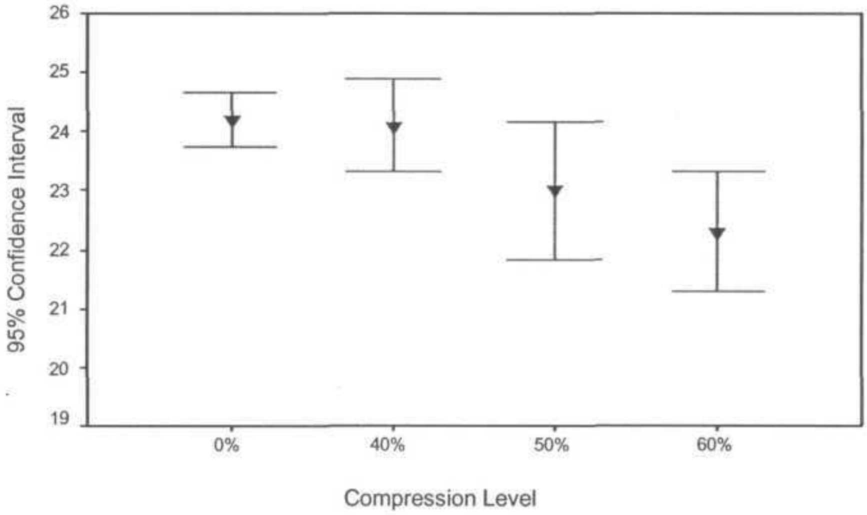
For the 9-9.11 year olds, the 0% compressed word scores was significantly different from the 50% compression scores, but not significantly different from the 40% compression. Surprisingly, the mean scores in this age group improved at the 60% compression and there was no significant difference between the scores got at the 0% compression and 60% compression (Table 4 & Figure 3).

Fig. 3: Error bar for 9 - 9.11 years



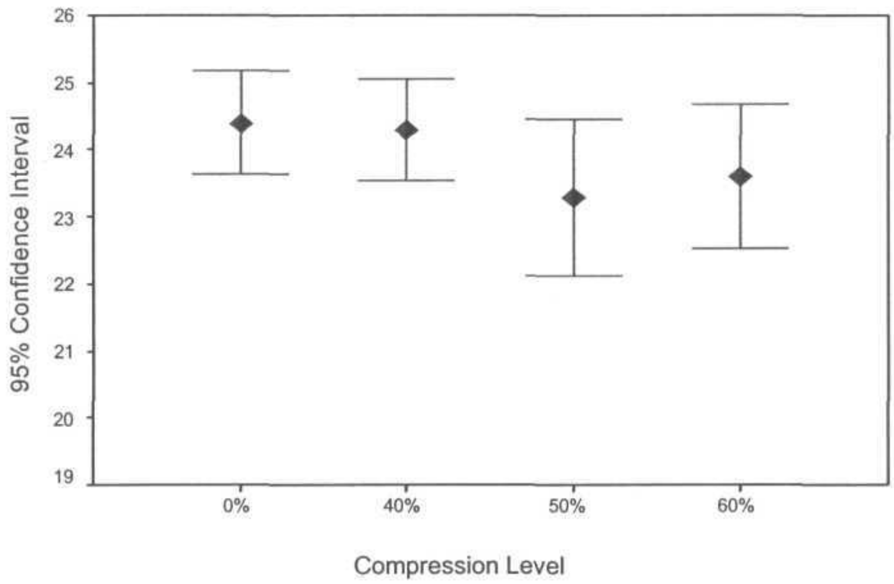
In the 10-10.11 year olds, their scores did not differ from the 0% compression score, until the compression reached 60%. There was no significant difference between the scores got at 0% compression and 40% compression as well as 0% and 50% (Table 4 & Figure 4).

Fig. 4: Error bar for 10 - 10.11 years



In the 11-11.11 year olds, there was no significant difference in scores with increase in compression level (Table 4 & Figure 5).

Fig. 5: Error bar for 11 - 11.11



The error bars shown in Figures 1 to 5 bring to light that there is an overlap in scores at each of the ages, with increase in compression level. It is also evident that the effect of compression is not uniform in each of the age groups.

The raw data indicated that for individual clients, there was generally a decrease in scores with an increase in compression level. Thus, it is recommended that for each client the scores should be compared at different compression levels rather than compare the scores with norms obtained at one compression level. This would provide more diagnostic information.

Research by Beasley, Bratt, and Rintelmann, (1980) has shown that in young adults, with increase in compression levels, the scores varied very marginally up to 60% compression. The compression level had to be increased to 70%, before the scores dropped significantly.

Thus, it can construed that compressions up to 60% do not result in significant variation in scores, in individuals who are normal hearing. It needs to be investigated whether individuals with a temporal processing problem show marked differences across compression levels, unlike that reported in normal hearing subjects in the study by Beasley et al. (1980) and in the present study.

b) Effect of compression across ages

MANOVA was done to find out the effect of the level of compression across ages. The results indicated that there was no significant age effect at the 0% and 60% compression levels. However, there was a significant age effect at the 40% and 50% compression levels (Table 5). From this it can be inferred that when the task is very easy (0% compression level) or very difficult (60% compression level), the subjects across different ages perform in a similar manner. However, when the task was of moderate difficulty (40% and 50% compression levels), the effect of maturation was evident. This occurred when the scores of all 60 subjects was analyzed. The analysis was also done after deleting the scores of the ten subjects with very high scores at higher levels of compression. When this was done the scores varied across ages for the 60% compression also (F (4,45) = 2.327, p> 0.1).

Table 5: - Significance of difference between ages at different compression levels for 60 subjects.

Level of compression with reference to age	F-value	p-value
0%	F(4,40)= 1.380	>0.05
40%	F (4,40) = 3.679*	<0.05
50%	F (4,40) = 3.802*	<0.05
60%	F (4,40) =1.658	>0.05

p significant at 0.05 level

The Duncan's Post-hoc test was done for the 50 subjects in order to find out the effect of each compression level across age levels (Table 6). At the 40% compression level, the youngest age group (7 years-7.11 years) performed significantly poorer than all the older age groups (8 years-11.11 years). However, there was no maturational change from 8 years onwards at this compression level. At the 50% compression level, the youngest group (7 years-7.11 years) performed significantly poorer than the older two groups (10 years-11.11 years). However, they did not differ from the adjacent two age groups (8 year-8.11 years and 9 year-9.11 years). At the 60% compression level, the trend was little different from that seen at the 40% and 50% compression levels. Here, the youngest age groups (7 years-7.11 years) performed significantly poorer than only the oldest age group (11 years-11.11 years). The 8 years-8.11 years old children also had scores that were significantly different from the oldest group. There was no significant difference between the other age groups.

The finding reveals that when there was no compression (0%), there is no difference in the scores at different ages. However, when compression was introduced a developmental trend was observed. The developmental trend varied depending on the level of compression.

It has also been reported by Sujitha (2005) that scores on a compression test does vary across ages, in children. The developmental trend observed by her was not similar to what was observed in the present study. This variation could be due to the material used. While she used CVC monosyllables, CVCV bisyllables were used in present study. Hence, there was a higher chance of consonantal information being deleted from a stimulus, in her study then in the present study. It was also observed in her study that the mean scores across ages was lower than that seen in the present study. This could be accounted for by the greater reduction in consonantal information in her study, when compared to the present study.

De Chicchis, Orchik, & Tecca, (1981) also noted that significant variation in scores are obtained in time-compression tests depending on the material used. They noticed the variation at 30% and 60% compression levels.

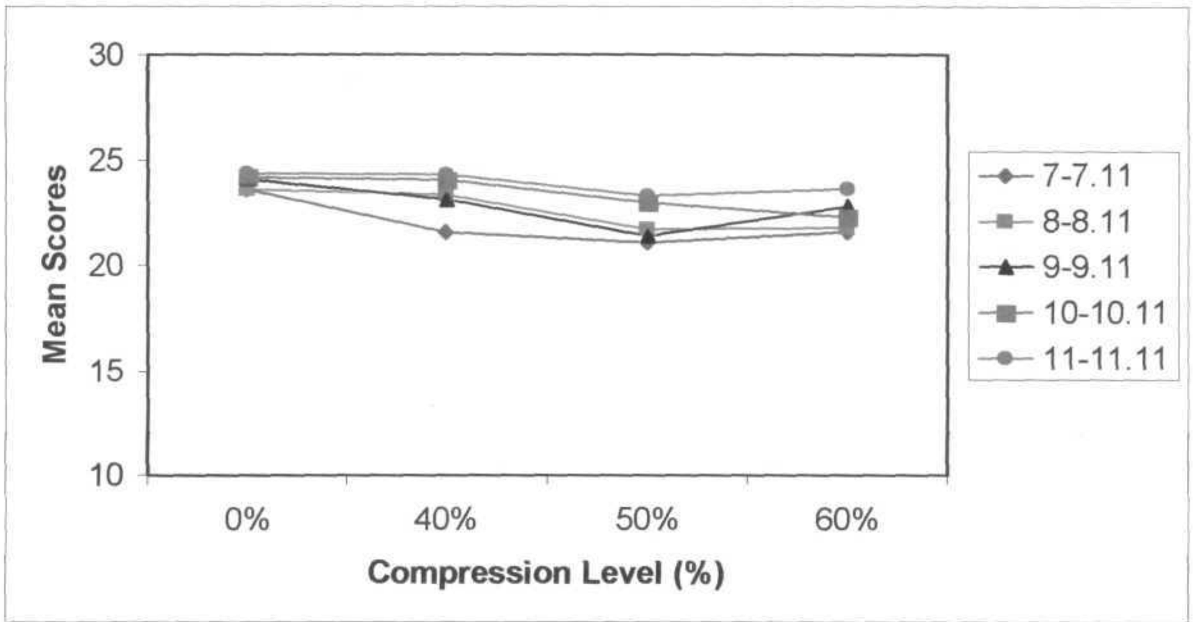
This finding of the studies in the literature and in the present study indicate that norms obtained in one test material cannot be used for another test material.

Table 6: - Significance difference between different age groups, across compression Levels

Ages (in years)	Level of compression			
	0%	40%	50%	60%
7-7.11 & 8-8.11	NS	YES	NS	NS
7-7.11 & 9-9.11	NS	YES	NS	NS
7-7.11 & 10-10.11	NS	YES	YES	NS
7-7.11 & 11-11.11	NS	YES	YES	YES
8-8.11 & 9-9.11	NS	NS	NS	NS
8-8.11 & 10-10.11	NS	NS	YES	NS
8-8.11 & 11-11.11	NS	NS	YES	YES
9-9.11 & 10-10.11	NS	NS	YES	NS
9-9.11 & 11-11.11	NS	NS	YES	NS
10-10.11 & 11-11.11	NS	NS	NS	NS

*NS= Not significant

Figure 6:- Mean scores for different age groups across compression levels.



In conclusions, the results obtained from the present study indicate that:-

1. There was no significant difference in the right and left ear scores for the monotically presented time-compressed Kannada speech stimuli.
2. There was no difference in the performance of males and females across ages, at different levels of compression.
3. With increase in compression level, the scores generally dropped. However, the effect of compression at each of the age groups was not identical.
4. There was a significant decrease in performance seen with increase in the level of compression except for the oldest group.

5. The error scores indicated that there was an overlap in scores across the four compression levels.
6. In addition to using age appropriate norms while using the Kannada time-compressed speech test, it is recommended to compare individual scores at 0% compression with scores at 50% or 60% compression.
7. When there is shortage of time, testing can be performed at only two compression levels i.e. at 0% and 50% or 60% compression levels for all age groups.
8. There was no change in scores across ages at the 0% and 60% compression, when the scores of all the subjects was analyzed. Hence, if these two levels are being used, age appropriate norms are not required, while administering the Kannada time-compressed speech test.
9. At the 40% compression level and 50% compression level, there was a significant difference across ages. This variation in score was not linear across the ages. Thus, when the task was very easy (0% compression) or very difficult (60% compression), changes across ages did not occur. It occurred only when the task was of moderate difficulty.

SUMMARY AND CONCLUSION

The purpose of the present study was to develop a Time-Compressed Speech Test in Kannada. The recorded material developed by Yathiraj and Vijyalakshmi (2005) was used to construct the test. The compression levels used in the present study were 0%, 40%, 50% and 60%. Using the developed material, the study aimed at establishing normative data on a group of children. The study also aimed at investigating the effect of ear, gender, level of compression within and across different ages on the scores of the time-compressed words. The task involved identification of monotically presented time-compressed monosyllables. The subjects were tested either in the left ear or in the right ear.

The subjects taken for the study were 60 normal hearing children whose mother tongue was Kannada. The age range of the children was 7-12 years. None of the subjects had history of any neurological involvement. The subjects were initially tested to ensure normal auditory functioning prior to administering the Time-Compressed Speech Test in Kannada.

The responses were scored in terms of number of correct responses for different percentage of compression. The raw data were analyzed using descriptive statistics as well as a three way MANOVA.

The results revealed that:

1) There was no significant difference in right and left ear scores for the monotically presented time-compressed Kannada speech stimuli.
2) There was no difference in the performance of males and females across ages, at different levels of compression.
3) With increase in compression level, the scores generally dropped. However, the effect of compression at each of the age groups was not identical.
4) There was a significant decrease in performance seen with increase in the level of compression except for the oldest group.
5) The error scores indicated that there was an overlap in scores across the four compression levels.
6) In addition to using age appropriate norms while using the Kannada time-compressed speech test, it is recommended to compare individual scores at 0% compression with scores at 50% or 60% compression.
7) When there is shortage of time, testing can be performed at only two compression levels i.e. at 0% and 50% or 60% compression levels for all age groups.
8) There was no change in scores across ages at the 0% and 60% compression, when the scores of all the subjects was analyzed. Hence, if these two levels are being used, age appropriate norms are not required, while administering the Kannada time-compressed speech test.

9) At the 40% compression level and 50% compression level, there was a significant difference across ages. This variation in score was not linear across the ages. Thus, when the task was very easy (0% compression) or very difficult (60% compression), changes across ages did not occur. It occurred only when the task was of moderate difficulty.

The results from the present study support the findings of previous studies by Beasley et al. (1972a), Nagafuchi (1976), De Chicchis et al. (1981) and Sujitha (2005). Thus, the findings of the present study on the Indian population are consistent with the finding obtained on the western population and similar to the non-native English speakers. The present study also reveals that the time compressed speech test can be administered in any ear and in both males and females without adversely affecting the results.

It is recommended that the test be administered in individuals with a complaint of temporal processing. This would conform the utility of the test for diagnostic purposes.

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