LEXICAL NEIGHBOURHOOD TEST (LNT) FOR CHILDREN IN KANNADA

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CERTIFICATE

This is to certify that this dissertation entitled **"Lexical Neighbourhood Test (LNT) for Children in Kannada"** is the bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student with Registration No.: 10AUD002. 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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CERTIFICATE

This is to certify that this dissertation entitled **"Lexical Neighbourhood Test (LNT) for Children in Kannada"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any Diploma or Degree.

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DECLARATION

This is to certify that this Master's dissertation entitled **"Lexical Neighbourhood Test (LNT) for Children in Kannada"** is the result of my own study under the guidance of **Prof. Asha Yathiraj,** Professor of Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

Mysore　　　　　　　　　　　　　　　　　　　　Register No. 10AUD002.

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Introduction

As early as 1952, Hirsh et al. noted that speech tests have diagnostic and prognostic values. Speech audiometry continues to be considered essential due to its inherent advantage over pure-tone audiometry. Speech stimuli have been found to aid in detecting perceptual difficulties that may go undetected if only pure-tones were used. Pathologies in the retro-cochlear region and higher auditory pathways have been reported to not manifest themselves if evaluated only using pure-tones. This occurs despite the presence of marked speech perception difficulties. Hence, speech has been considered the preferred test material for assessing higher cortical functions (Jerger & Jerger, 1974; Jerger & Hayes, 1971). It has also been used in assessing the success in otological surgery (Kasden & Robinson, 1970), in determining communication abilities (Berger, Keating & Rose, 1971) and for hearing aid evaluation (Markides, 1977). Also, speech audiometry has been noted to help in early detection of slight losses which are otherwise overlooked (Ritchie & Merklein, 1972). The need for speech audiometry has arisen mainly because speech is by far the most important class of sound that one hears.

Several speech identification tests have been developed for children (Ross & Lerman, 1970; Mayadevi, 1974; Elliot & Katz, 1980; Moog & Geers, 1990; Rout, 1996; Vandana, 1998; Prakash, 1999; Begum, 2000; Chowdary, 2003; Jijo & Yathiraj, 2008). However, these tests have been observed not to address difficulties faced by all children, especially those using cochlear implants (Cullington, 2000) as these children greatly vary in their spoken word recognition skills (Staller, Beiter, Brimacombe, Mecklenburg, & Arndt, 1991). This variability depends in part on the age of onset and duration of their hearing loss (Fryauf-Bertschy, Tyler, Kelsay, &

Gantz, 1992), and on the length of cochlear implant use (Fryauf-Bertschy et al., 1992; Miyamoto et al., 1992, 1994). Thus, as children develop, there is a great need to have different levels of tests that increase in terms of their perceptual difficulty.

In order to assess the developing auditory skills in children as they grow, a number of speech perception measures have been developed. These speech perception tests range from very simple closed set tests like Pattern Perception Test (Moog & Geers, 1990), Word Intelligibility by Picture Identification test (Ross & Lerman, 1979), Northwestern University-Children's Perception of Speech (Elliot & Katz, 1980), Picture speech identification test for children in Tamil (Prakash, 1999) and in Hindi (Chowdry, 2003), Early Speech Perception test for Malayalam speaking children (Jijo & Yathiraj, 2008) to more complex open-set tests like Phonetically balanced word lists-Kindergarten (Haskins, 1949), Bamford-Knowal-Bench sentence test (Bench, Knowal & Bamford, 1979), Common phrase test (Robbins, Renshaw & Osberger, 1995) etc. However, it has been reported by Mukari, Ling and Ghani (2007) that children with cochlear implants performed poorly on the PB-K. This has been attributed to the test containing words that are unfamiliar to young deaf children who typically have very limited vocabulary.

The Lexical Neighbourhood Test (LNT) was developed by Kirk, Pisoni, and Osberger (1995) to assess spoken word recognition in order to reveal the perceptual processes employed by children, especially for those using cochlear implants. The LNT test items were formed based on the frequency of occurrence of word in the language (word frequency) and the number of phonetically similar words surrounding the word (lexical density). Words with many lexical neighbours were considered to have a 'dense' lexical neighbourhood, whereas those with only a few lexical neighbours were considered to have a 'sparse' neighbourhood. Based on word frequency and lexical density, 'lexically easy' and 'lexically hard' words were categorized. The lexically 'easy' words had more frequently occurring words with 'sparse' neighbourhood and lexically 'hard' words had less frequently occurring words with 'dense' neighbourhood.

The Lexical Neighborhood Test is considered to be very useful for measuring word recognition in children with multichannel cochlear implants who exhibit varying speech perception abilities. Thus, it is reported to provide reliable estimates of spoken word recognition abilities in these children. The test is believed to allow the examination of the perceptual processes underlying spoken word recognition. Further, the test is used to gain further knowledge about the organization of sound patterns of words in young children's lexicons and the processes used to access these patterns in traditional speech identification tests (Kirk et al., 1995).

LNT has been developed in various languages like Mandarin (Yang & Wu, 2005), Cantonese (Yuen et al., 2008), and Chinese (Liu et al, 2011). In India, it has been developed in Indian English by Patro and Yathiraj (2010) and in Hindi by Singh (2010).

Need for the study:

There are several word identification tests to determine the auditory perceptual difficulties of children with hearing impairment. At one extreme are simple tests such as the pattern perception test. On the other extreme are phonemically-balanced open-set word tests which can be made more difficult by adding distortion such as noise. As children are in the process of developing speech and language, there is a need for a speech identification test that is neither too easy nor too difficult. The LNT could serve as one such test that can test the perceptual difficulties as the children develop.

This would permit the evaluation of the auditory perceptual difficulty of children with hearing impairment before they get to the stage where they can be evaluated with PB words.

Though there are several speech identification tests for children developed in India (Swarnalatha, 1972; Mayadevi, 1974; Vandana, 1998; Prakash, 1999; Chowdary, 2003; Jijo & Yathiraj, 2008), they have been developed taking into account only the familiarity of the stimuli. However, it is evident from literature (Kirk et al., 1995; Dirks, Takayana & Moshfegh, 2001; Krull, Choi, Kirk, Prusick & French, 2010) that despite words being familiar, word frequency and lexical density, also need to be considered. This would provide perceptual information of two different dimensions regarding the perception of speech. This would be especially useful in evaluating the subtle perceptual difficulties of children using listening devices such as hearing aids or cochlear implants. The results from the test would serve as guidelines regarding the usefulness of the devices. In addition, the test would help determine the progress made by children using these devices over time, with or without training. In India it is currently available only in Indian English (Patro & Yathiraj, 2010) and in Hindi (Singh, 2010).

When speech is used as stimuli for assessment, the regional language used for testing becomes an important variable (Alusi, Hinchcliffe, Ingham, Knight & North, 1974). An individual's perception of speech has been found to be influenced by his first language or mother tongue (Singh, 1966; Gat, 1978). India being a multilingual country, it is necessary to develop tests for the paediatric population in different Indian languages. Currently, LNT is not available in Kannada and hence there is a need to develop such a test in the language.

Aim of the study

The aim of the study was to develop a Lexical Neighbourhood test in Kannada for children aged 6-8 years. The study also aimed to check the utility of the developed test on the target group and in children with hearing impairment using cochlear implants.

Objectives / Hypotheses of the study:

- To evaluate the developed lexical neighbourhood test material for Kannada on typically developing children and children with hearing impairment who were exposed to the language since early childhood,
- To compare the performance of 'easy' and 'hard' words across children aged 6-7 years and 7-8 years,
- To check if the scores obtained by the two age groups were different for 'lexically easy' and 'lexically hard' words,
- To check if the two developed lists of the LNT were equivalent or not,
- To check if there was any difference in the performance for children with normal hearing and children with hearing loss using cochlear implants.

Prior to studying these objectives, a review of literature was carried out regarding speech identification tests developed specifically to assess children using cochlear implants. Factors that influence the outcome of such tests were also reviewed in order to control these variables while developing the test.

Review of Literature

Technological advances have lead to enhanced perception of speech in individuals with hearing impairment. To confirm that devices such as cochlear implant do enhance speech perception abilities, Cowan et al. (1995), Dowell and Cowan (1997), Osberger (1998), and Wang, Wu and Kirk (2010) emphasised the importance of verification of spoken word recognition by means of appropriate test materials. The evaluation of spoken word recognition abilities has been found to provide important clinical information about the appropriateness of auditory devices and progress over time.

Several different types of tests have been used to assess the perceptual benefit of cochlear implants in children. Closed-set tests, which provide the listener with a limited number of response alternatives, have been used to measure the perception of prosodic cues, vowel and consonant identification and word identification. According to Tyler (1993), approximately 50% of children with multichannel cochlear implants perform significantly above chance on closed set word identification tests and some obtain very high levels of performance (70% to 100% correct). The perceptual problems of the latter group were noted to be tapped only with the use of open-set word recognition tests that taxed the auditory mechanism.

Open-set word recognition is considered an important diagnostic measure for determining the benefit of auditory devices in the children (Osberger et al., 1991; Dowell, Blamey & Clark 1995). Wang et al. (2010) observed that such tests indicated the neural representation of words in their long-term lexical memory which is required for spoken language.

The evaluation of open-set spoken word recognition has been used for decades as a clinical and research instrument with children with hearing impairment to determine the benefits of sensory aids such as hearing aids or cochlear implants. The Phonetically Balanced Kindergarten word lists (PB-K) developed by Haskins (1949) has been a very popular open-set speech recognition tests. However, studies have found that children with cochlear implants generally performed relatively poorly on the PB-K (Osberger et al. 1991; Staller, Beiter, Brimacombe, Mecklenburg & Arndt, 1991; Fryauf-Bertschy, Tyler, Kelsay & Gantz, 1992; Miyamoto, Osberger, Robbins, Myers & Kesler, 1993). Osberger et al. (1991) reported that the mean PB-K score for 28 subjects with approximately 2 year of cochlear implant use was 11% (ranging from 0% to 36%). Similarly, Staller et al. (1991) reported that the mean PB-K scores was approximately 9% words for 80 children who had 1 year of multichannel cochlear implant experience. It was opined by Kirk, Pisoni & Osberger (1995) that the PB-K did not distinguish children with differing spoken word recognition skills and did not measure changes due to increased device experience as the scores of the subjects clustered in a restricted range near 0%. Furthermore, Kirk et al. (1995) observed that the parents and educators of children with cochlear implants were found to report of a discrepancy between the observed performance on phonetically balanced word lists and their real-world or everyday communication abilities in more natural settings. It was noted that despite the children obtaining very low scores on phonetically balanced word lists, they demonstrate relatively good performance during daily activities.

It has been reported that a possible reason for the poor performance of children with cochlear implants on the PB-K test was the constrain created by phonetic balancing. This was found to result in lists containing words that were unfamiliar to young children with deafness who typically have very limited vocabularies (Dale, 1974; Lach, Ling & Ling, 1970; Quigley & Paul, 1984). Also, Tobias (1964), Carhart (1965) and Hood and Poole (1980) demonstrated that phonetic balancing was not needed to achieve equivalent word lists.

To overcome the problems posed by conventionally used speech identification word tests, the Lexical Neighbourhood Test (LNT) was developed by Kirk et al. (1995). This spoken word recognition test was designed to assess the perceptual processes employed by children, especially those using cochlear implants. Phonetic balancing was not considered in the LNT construction as it was found unnecessary towards word lists equivalency. In the LNT, the words were constructed taking into account the 'neighbourhood density' and 'word frequency'. These aspects were considered since the lexical characteristics such as the frequency with which words occurred in a language (Andrews, 1989; Elliot, Clifton & Servi, 1983) and the number of phonemically similar words in the language (Treisman, 1978a, 1978b) had been shown to influence the spoken word recognition (Luce, 1986; Luce, Pisoni & Goldinger, 1990).

Influence of word frequency:

The issue of word frequency has been considered important in the investigation of the structural organization of the sound patterns of words. Numerous studies over the years (Howes, 1954, 1957; Newbigging, 1961; Savin, 1963; Soloman & Postman, 1952) have demonstrated that the ease with which spoken words were recognized was monotonically related to experienced frequency, as measured by some objective count of words in the language. It was inferred that if word frequency influenced the perceptibility of the stimulus word, it should have also influenced the degree of activation of similar words in memory. Thus, Luce and Pisoni (1998) concluded that frequency of occurrence is important when specifying the relative competition among activated items that are to be discriminated.

Numerous processing advantages have been demonstrated for more frequently occurring words (Luce & Pisoni, 1998). Many theories have also been proposed to account for the advantages associated with increased word frequency. These theories have cited frequency of exposure (Forster, 1976; Morton, 1969), age of acquisition (Carroll & White, 1973a, b), and the time between the present and last encounter with the word (Scarborough, Cortese, & Scarborough, 1977) as the underlying reasons for the processing advantages observed for very frequently occurring words. It was widely assumed by many researchers (Broadbent, 1967; Savin, 1963; Triesman, 1971, 1978a, 1978b) that frequency served to bias the word recognition system toward choosing more frequently occurring words over less frequently occurring words. However, Havens and Foote (1963) demonstrated using a visual word recognition task that the effects of word frequency of occurrence could be eliminated if the number of neighbours for a given word were controlled. Thus, less frequently occurring words were identified at levels of accuracy equal to those of more frequently occurring words when the number of neighbours were held constant. This result suggested that the effect of frequency of occurrence of word was dependent on the neighbourhood in which the word resided in the lexicon.

In 2010, Krull, Choi, Kirk, Prusick and French studied the effect of frequency of occurrence on spoken word recognition and confirmend that performance for more frequently occurring words was significantly better than that for less frequently occurring words. However, it was reported that the result was a bit more complicated due to an interaction between word frequency and lexical density.

From the above studies it can noted that the frequency of occurrence plays an important role in spoken word recognition. However, a few studies (Triesman, 1978a, 1978b; Krull et al., 2010) also reported that effect of frequency of occurrence was influenced by lexical density. Thus, it becomes important to study the influence of lexical density on spoken word recognition.

Influence of lexical density/ neighbourhood density:

The lexical neighbour of a given word has been defined as all of the words differing from the target word by one phoneme by substitution, deletion, or insertion (Greenburg & Jenkins, 1964; Landauer & Streeter, 1973). The term lexical density had been used to refer to the number of phonemically similar words to the target word (Luce, 1986). Words with many lexical neighbours were considered to have a ‘dense’ lexical neighbourhood, whereas those with only a few lexical neighbours were considered to have a ‘sparse’ neighbourhood. In several experiments, Luce and Pisoni (1998) found that words with few lexical neighbours were recognized better and were processed more quickly in lexical decision and naming tasks than words with many neighbours.

Studies in relation to lexical density alone are sparse. Anderson (1962) examined the effects of the nature and number of lexical neighbours on the intelligibility of spoken words. It was demonstrated that the intelligibility of spoken words was affected by both the neighbourhood density as well as by neighbourhood frequency (the frequencies of occurrence of the neighbours). Anderson showed that target words with more neighbourhood density were less intelligible than words with lesser neighbourhood density.

In general, studies indicated that the neighbourhood structure may play an important role in word recognition. Hence, when evaluating subtle perceptual difficulties of individuals with hearing impairment, it is essential to assess this aspect.

Combination of lexical density and word frequency:

Studies determining the impact of both lexical density and word frequency are considerably more than those that evaluate the influence of each one of these factors independently. Both word frequency and lexical density have been found to affect spoken word recognition. Kirk et al. (1995) used the terms 'lexically easy' and 'lexically hard' words based on word frequency and lexical density. The lexically 'easy' were words that had more frequently occurring words with 'sparse' neighbourhood and lexically 'hard' words had less frequently occurring words with 'dense' neighbourhood.

Luce and Pisoni (1998) also demonstrated that both neighbourhood density and neighbourhood frequency contributed to the variance in perceptual word recognition. They reported that speed and accuracy of identifying words was best predicted by simultaneously taking into account word frequency and neighbourhood density. Luce and Pisoni thus suggested the Neighbourhood Activation Model (NAM) which emphasized the importance of lexical discrimination on word recognition and suggested that tests of speech pattern and phonetic feature discrimination alone may not explain the complex process of word recognition. NAM suggested a two-stage process for word recognition. The first stage involved 'phonetic processing' followed by a second stage in which 'lexical selection' occurred. Thus, in the first stage (phonetic processing), a stimulus input was considered to activate a set of similar acoustic-phonetic representations in memory. This initial stage of activation was followed by a process of 'lexical selection' among a large number of potential candidates that were consistent with the acoustic-phonetic input. Here, word frequency was assumed to act as a biasing factor by multiplicatively adjusting the activation levels of the acoustic-phonetic representations.

The effect of lexical characteristics on spoken word recognition by paediatric cochlear implant users was evaluated by Kirk et al. (1995). The results revealed that both word frequency and lexical density affect spoken word recognition. Improved word recognition on the lexically easy words was observed for both monosyllabic and multisyllabic stimulus words. Thus, Kirk concluded that these subjects appeared to organize familiar words into similarity neighborhoods in long-term memory, and used this structural information in word recognition in a manner similar to listeners with normal hearing (Luce, 1986**;** Luce et al., 1990; Charles-Luce & Luce, 1990**;** Cluff & Luce, 1990).

Dirks, Takayana & Moshfegh (2001) studied the effect of lexical factors on word recognition among normal-hearing and hearing-impaired listeners. Two word lists, based on the lexical characteristics of word frequency and neighborhood density and frequency were developed (lexically ‘easy’ words and lexically ‘hard’ words). Simple and transformed up-down adaptive strategies were used to estimate performance levels at several locations on the performance-intensity functions of the words. The results verified the predictions of the NAM and showed that easy words produced more favorable performance levels than hard words at an equal intelligibility. Although the slopes of the performance-intensity function for the hearing-impaired listeners were less steep than those of normal-hearing listeners, the effects of lexical difficulty on performance were similar for both groups.

Recently, Krull et al. (2010) also examined the effect of word frequency and lexical density on spoken word recognition in children with normal hearing aged 5 and 12 years. Testing was performed in noise in order to eliminate the possibility of ceiling effects when testing children with normal hearing in quiet. The results showed that word frequency and lexical density influenced word recognition both independently, and in combination. Lexical density appeared to be more heavily weighted than word frequency in children. They made this conclusion since words with sparse neighbourhood yielded greater accuracy than words with dense neighbourhood, irrespective of the frequency of occurrence of words.

Thus, most of the studies, as quoted above, report that there is combined influence of frequency of occurrence of word and lexical density on spoken word recognition and thus highlights the importance of considering both the parameters in developing a test material to assess the speech perception abilities in children using amplification devices. As reported earlier, one such test developed considering both these parameters is LNT.

The Lexical Neighbourhood Test (LNT) and Multisyllabic Lexical Neighbourhood Test (MLNT), developed by Kirk et al. (1995) were based on the assumptions of the Neighbourhood Activation Model (NAM). They categorised words into 'similar neighbourhoods' based on their frequency of occurrence in the language (word frequency) and number of phonetically similar words surrounding the word (lexical density). The LNT consisted of two 50-item lists of monosyllabic words and within each list half the items were lexically easy and half were lexically hard. Lexical difficulty was determined using Logan's (1992) analysis of the lexical properties of words in the CHILDES database (Mac-Whinney & Snow, 1985).

Kirk et al. (1995) studied the effects of word frequency, lexical density and word length. They also examined the performance on the PB-K, LNT, and MLNT in a group of 28 paediatric cochlear implant users. All tests were administered via live voice. The results demonstrated that word recognition performance was significantly higher for the LNT word lists than for the PB-K, suggesting that the PB-K underestimates spoken word recognition in these children. Performance also was significantly better for the multisyllabic stimuli on the MLNT than for the monosyllabic stimuli on the LNT which indicated that these children were able to use linguistic redundancy and context (i.e., word length) to aid them in spoken word recognition. Finally, the results revealed that children with cochlear implants identified lexically easy words with greater accuracy than lexically hard words. This latter finding suggests that even children with cochlear implants were sensitive to the acoustic-phonetic similarities among spoken words, that they organize spoken words into similarity neighbourhoods in long-term memory. The study revealed that the children used this structural information and context in recognizing isolated words.

Research has shown that the performance of easy and hard words can be influenced by various factors. Thus, in order to efficiently develop a test following the basis of the LNT/MLNT, it is important to know the factors influencing the perception of easy and hard words.

Factors influencing the perception of easy and hard words:

Open-set Vs. Closed-set tasks:

It has been noted by Clopper, Pisoni, and Tierney (2006) that in closed-set tests, the competition between alternatives is limited to the response set provided to the client/participant. However, in open-set tests of spoken word recognition, the lexical competition has been noted to exist at the level of the entire mental lexicon.

Sommers, Kirk, and Pisoni (1997) examined the effects of lexical difficulty on word recognition performance among subjects with normal hearing, masked normal hearing, and patients wearing cochlear implants using both open and close-set response formats. The crucial finding was that in a closed-set format, there was no effect of easy versus hard words. However, robust effects of lexical difficulty were obtained in the open-set format wherein hard words were identified less accurately than easy words. The authors thus concluded that closed-set formats do not allow adequate evaluation of the full range of complex perceptual and cognitive processes necessary for recognizing spoken words. According to the authors, the absence of frequency and density effects in closed-set speech discrimination tests demonstrated that the test does not measure word recognition or lexical access. Instead, the test measured speech pattern discrimination, which they opined could be accomplished without accessing words from the lexicon. They demonstrated that in closed-set formats, effects of lexical difficulty, which include effects of stimulus word and neighbour frequency, were attenuated.

The recognition of easy and hard words using closed-set and open-set task formats was also studied by Clopper et al. (2006). Sixty listeners were presented with 132 words which were presented in three blocks (44 words per block). The first block involved a open set task and the other two were carried out as closed set tasks. Each block contained 22 ‘easy’ words and 22 ‘hard’ words. The results revealed that the effects of lexical competition were seen with open-set word recognition tasks but not with closed-set tasks. The authors concluded that this failure to find lexical competition effects using closed-set word recognition tests might be because listeners do not necessarily need to access or contact the lexicon to perform the closed-set speech intelligibility task. Instead, they use a more general pattern-matching strategy which may result in equal performance for both easy and hard words.

From the finding of open and closed-set test on the perception of easy and hard words, it is evident that word difficulty cannot be determined through closed-set tasks. Such perceptual differences can be observed only through the use of open-set tasks.

Syllable length / word length:

The impact of syllable length on speech perception has been documented over several decades (Charles-Luce, Luce & Cluff., 1990; Cluff and Luce, 1990). It has been observed that multisyllabic words are better identified than monosyllabic words (Kirk et al., 1995; Yuen et al., 2008; Wang et al., 2010; Liu et al., 2011). However, for both monosyllabic and multi-syllabic words, word recognition was significantly better on the easy words than on the hard words.

Kirk et al. (1995) studied the effect of word length on spoken word recognition and demonstrated that subjects were significantly better at recognising multi-syllabic words than monosyllabic words. This was considered to occur probably because multisyllabic words have fewer lexical neighbours than monosyllabic words, thus minimising competition in the lexical selection. Kirk concluded that the lexical properties influenced multisyllabic word recognition and that word frequency was an important factor contributing to lexical effects of multisyllabic word recognition, as the variability in neighbourhood lexical density was small.

In a later study, Kirk, Mc-Cutcheon, Sehgal and Miyomoto (2000) offered two possible reasons for the lexical length influence occurring. First, the linguistic redundancy cues in multisyllabic words were considered to aid spoken word recognition. Second, multisyllabic words come from relatively sparse lexical neighbourhoods compared with monosyllabic tokens. That is, multisyllabic words have fewer phonetically similar words, or neighbours, competing for selection than do monosyllabic stimuli.

Similar findings have been reported in Cantonese (Yuen et al., 2008), Mandarin (Wang et al., 2010) and Chinese (Liu et al., 2011). In all these studies done in different languages, disyllabic/ multisyllabic easy and hard words were better identified than monosyllabic easy and hard words.

From the above results it can be inferred that multisyllabic words are more influenced by word frequency of occurrence (as they have sparser neighbours) than monosyllabic words. In contrast, monosyllabic words are more influenced by lexical density (as they have denser neighbours compared to multisyllabic words). Further, both monosyllabic and multisyllabic words speech recognition was better for easy words than for hard words. Also, from all these results it can be implied that multisyllabic speech perception tests may serve as a useful tool in assessing the underlying perceptual processes in those children with limited auditory perceptual abilities obtaining poor scores with monosyllabic words.

Scoring procedure (Word scores Vs. Phoneme scores):

According to Kirk et al. (1995) word recognition was significantly poorer than phoneme recognition on both the LNT and MLNT. When only word scores were considered, lexical difficulty was found to be highly significant [$F(1, 391) = 20.03$, $p < 0.0001$]. That is, performance on the ‘easy’ words was significantly better than on the ‘hard’ words. When only phoneme scores were analyzed, effect of lexical difficulty was not found to be significant. That is, the performance was similar on both easy and hard words. Furthermore, word recognition performance was found to decrease with increasing list difficulty, but phoneme recognition did not. This correlation between word and phoneme recognition performance suggested that phoneme recognition may reflect an important first stage of speech recognition, without undergoing the second stage of speech processing, i.e. lexical selection. Since similar results were noted in cochlear implant users also, Kirk commented that even children with hearing impairment using such devices perceive words in the context of other phonemically similar words in their lexicon, rather than as merely a sequence of unrelated sounds.

Thus, as reported from the above study, lexical effects were observed for word recognition but not for phoneme recognition. However, there are fewer studies comparing the word scores and phoneme scores on the perception of easy and hard words and thus more research would be required to confirm the above findings on the same.

Hearing Impairment:

Many studies related to the effect of lexical characteristics on spoken word recognition have been reported in individuals with hearing impairment using cochlear implants / hearing aids (Kirk et al., 1995; Yang & Wu., 2005; Yuen 2008; Patro & Yathiraj, 2010; Singh, 2010). Most of these studies have compared the performance of children with hearing impairment on the easy and hard words.

Kirk et al. (1995) studied the effect of lexical difficulty in English in 28 cochlear implant users and found that individuals with hearing impairment performed more accurately on easy words than on hard words. Thus, Kirk reported that even hearing impaired individuals do use their lexical knowledge in word recognition tasks.

In 2005, Yang and Wu in 28 cochlear implanted Mandarin speaking children found that there was a significant difference between ‘easy’ and ‘hard’ words. The authors concluded that the Mandarin-speaking children with cochlear implants were sensitive to the acoustic-phonetic similarities among lexical words and could organize words into similarity neighborhoods in long-term memory. Similarly, Yuen et al. (2008) have found similar findings in Cantonese language in both hearing aid users and cochlear implant users. Also, Patro and Yathiraj (2010) found the same in children with hearing impairment using hearing aids in Indian English.

Thus, from the above studies it can be noted that hearing impairment influenced the performance on easy and hard words with easy words being recognised more easily and accurately than hard words. This implies that even children with hearing impairment are sensitive to the effects of lexical characteristics and thus recognise easy and hard words differently with easy words being recognised more easily than the hard words.

Age:

Sommers (1996) examined the perception of ‘easy’ and ‘hard’ words in young and older adults. It was found that normal-hearing older adults were more strongly affected by similarity neighbourhood composition than were young adults. In particular, the older adults showed more decrement in identification accuracy for hard words than did the younger adults, suggesting that a portion of age-related difficulties in spoken word recognition may have stemmed from factors other than peripheral hearing loss, such as the reduced ability to process multiple activated words in memory.

Liu et al. (2011) studied the effect of age on spoken word recognition using easy and hard words. Ninety-six native Standard-Chinese speaking normal hearing listeners were considered and were divided into three groups according to age (4;0 to 4;11 years, 5;0 to 5.10 & 6;0 to 6;11 years). The results revealed that the mean scores increased along with age. The average scores for 'easy' word lists were 93.5%, 96.1%, and 97.9% correct for the children aged 4;0 to 4;11 years, 5;0 to 5.10 & 6;0 to 6;11 years, respectively. For the 'hard' word lists, the perceptual scores were 86.41%, 88.48%, and 92.92% correct in the three age groups. In any of the lexical categories, it was noted that the test scores were always significantly higher in the 6-year-old group than those of the 4-year-old group, whereas the scores did not differ significantly between 6 and 5 year old group. Liu et al. came up with two potential reasons that may account for these results. Firstly, that language development for children at certain stage of age might be comparatively slow and thus may not show much improvement on speech recognition. Secondly, that since the test stimuli were derived from the database of daily speech materials for children of ages between 3 and 5 years, the performance of 5 and 6-year old children might have potentially reached the ceiling effect, which might explain the lack of statistically significant differences between the 5 and 6- year-old groups.

Moore (2002) found that improvement in perceptual skills paralleled the anatomical development process of the auditory cortex which reached a level that was equivalent to young adults by 11 to 12 years of age. Thus, the influence of age on spoken word recognition was considered to be necessary making it necessary to obtain age appropriate norms for proper interpretation of speech perception abilities in children.

From above literature it can be noted that various procedural factors (open-set Vs. closed-set tasks, syllable length, and scoring procedure) and subject factors (hearing impairment, age) influence the performance of easy and hard words. Thus, all the above factors influencing the lexical characteristics need to be considered during spoken word recognition assessment.

LNT in other languages:

Monosyllabic Lexical Neighbourhood Test (M-LNT) was developed in Mandarin language by Yang and Wu (2005) for pre-school children. The test contained eight lists of 25 monosyllables in Mandarin, with four lists of lexically 'easy' words and four lists of lexically 'hard' words. All test items were generated from the cross-sectional database of 80 normal children aged 2 to 6, with 20 children (almost equal numbers of girls and boys) in each age group of six-month intervals. The M-LNT was further verified on 28 children using cochlear implants. The authors concluded that the Mandarin-speaking children with cochlear implants were sensitive to the acoustic-phonetic similarities among lexical words and could organize words into similarity neighbourhoods in long-term memory.

In 2010, Wang et al. using the Mandarin LNT and MLNT developed by Yang and Wu in 2005, examined the effects of word frequency and lexical neighbourhood density on spoken word recognition. They studied the effect of the monosyllables and disyllables on normal hearing children and children with cochlear implants. Word recognition scores were higher among disyllables than among monosyllables. Lexically 'easy' disyllabic words were better recognized than were their 'hard' counterparts. However, no lexical effects on word recognition of Mandarin monosyllables were observed for either group. Thus, the results did not fully support the predictions of the NAM. The findings suggested that a high proportion of homophones in Mandarin monosyllabic word stimuli interfere and decrease the lexical effects of word recognition in Mandarin for those children with normal hearing and those using cochlear implants. Thus, word frequency seems to contribute a more significant factor to word recognition than neighbourhood density.

Yuen in 2008 developed LNT in Cantonese language. Six monosyllabic and six disyllabic word lists were generated from the Cantonese CHILDES language database, constructed according to the Neighbourhood Activation Model. There were three lexically 'easy' and three lexically 'hard' word lists in each sub-test, with 25 items in each list. Four paediatric cochlear implant users and 10 hearing aid users, with bilateral congenital severe to profound sensori-neural hearing impairment participated in the study. All the children were below the age of 10 years. Similar to the findings of previous studies, word recognition was higher among disyllables than monosyllables and lexically 'easy' words were better recognized than 'hard' words.

Later in 2011, Liu et al. developed a Standard-Chinese version of the LNT and also examined the lexical and age effects on spoken-word recognition in normal-hearing children. The test contained six lists of monosyllabic and six lists of disyllabic words with 20 words per list. The words were selected from a database of daily speech materials for normal-hearing (NH) children aged 3–5 years. Ninety-six normal hearing children were tested with the Standard-Chinese monosyllabic and disyllabic LNT. The inter-list performance was found to be equivalent and inter-rater reliability was high with 92.5 to 95% consistency. Also, the lexical effects were all significant. Children scored higher with disyllabic words than with monosyllabic words. This was attributed to the more redundant information in the disyllables than in the monosyllables. ‘Easy’ words scored higher than ‘hard’ words. The word-recognition performance also increased with age in each lexical category. These results were consistent with those in other languages, supporting the application of NAM in Standard-Chinese language.

In India, LNT has been developed in Indian English by Patro and Yathiraj (2010) for children aged 6 to 8 years. The test was administered on 30 typically developing children and 5 hearing aid users. The test containing 2 lists, each having 10 lexically easy words and 10 lexically hard words, was found to be useful in providing information about the way children organized and accessed spoken words from long-term lexical memory. The study revealed that there was a significant effect of lexical properties on spoken word recognition scores in both children with normal hearing as well as those with hearing impairment. The lexical easy words were better perceived than lexical hard words. Age and hearing impairment was found to have a significant effect on the performance of the children on both lexically easy and lexical hard words.

LNT was also developed in Hindi by Singh (2010) which consisted of 2 word lists with 40 words each. One list consisted of lexically easy words and the other list had hard words. Both the lists were administered on 30 children with normal hearing and 7 children with mild-moderate hearing loss who wore hearing aids. It was found that in both the groups, perception of lexically easy words were better than the hard words. The author reported that in both the groups, words were recognized relationally in the context of other phonemically similar words in the lexicon and thus highlighted the importance of considering the effects of lexical characteristics on spoken word recognition.

The results of the above studies in different languages provided support to the NAM theory. In other words, the NAM theory can be applied to different languages. The development of the LNT in different languages has important clinical applications in assessment of speech perception abilities in hearing impaired children who have received hearing aids or cochlear implants.

Application of LNT:

Application of LNT in the clinical population:

The LNT is considered to provide reliable estimates of spoken word recognition in children using cochlear implants regardless of their overall performance levels (Kirk, Eiesenberg, Martinez & McCutcheon, 1998). It has also been found to serve as an important measure of progress over time in children using cochlear implants or other sensory aids. Further, it has been considered to provide information about the underlying factors that influence spoken word recognition in children with hearing impairment. Thus, LNT was found to provide important diagnostic information about the way these children processed spoken language. In children who did not show the expected lexical effects on spoken word recognition, it was construed that they may be organizing and accessing words from memory in a different way than listeners with normal hearing. Furthermore, the magnitude of lexical effects on spoken word recognition was considered to yield important information about how well children can make fine acoustic-phonetic distinctions among phonetically similar words. Relatively gross acoustic cues available from coarse coding of the speech signal was considered to be sufficient to identify many lexically easy words in sparse neighbourhoods, but finer acoustic-phonetic encoding was considered necessary to access lexically hard words from dense neighbourhoods. Thus, a large decrease in the identification of lexically hard words compared to easy words might suggest that a child is unable to encode the fine acoustic-phonetic cues available in the speech signal (Kirk et al., 1998).

Prediction of other measures of speech perception and spoken language from LNT:

Several recent studies have shown that performance on the LNT and MLNT is significantly correlated with other measures of spoken word recognition and spoken language processing in children with cochlear implants. The performance of CI subjects on the LNT was highly correlated with the results of the PB-K test, although, the PB-K test was harder than the LNT (Eisenberg, Shannon, Martinez, Wygonski & Boothroyd, 2000).

Pisoni, Svirsky, Kirk and Miyamoto (1997) examined the relationship between various measures of spoken language processing in a group of paediatric cochlear implants users with exceptionally good speech perception abilities. The results revealed that spoken word recognition performance on the LNT and the MLNT significantly correlated with open-set sentence recognition ($r > 0.80$) in the auditory-only modality as measured by the Common Phrases test (Robbins, Renshaw & Osberger, 1995). Performance on the LNT and MLNT also significantly correlated with the children's speech intelligibility ($r > 0.71$). In a separate study, Kirk (1996) found that word recognition performance on the LNT correlated significantly with receptive language abilities on the Reynell Language Developmental Scales for children who used Oral Communication, but not with those who used Total Communication. Additionally, Pisoni and Geers (1998) found a significant correlation between the spoken word recognition of children with cochlear implants, as measured by the LNT, and their ability to recall lists of digits presented through listening alone ($r > 0.58$).

The investigations cited above suggest that the LNT and MLNT are measuring something about the encoding, storage, retrieval and manipulation of spoken language. As such it appears that measures of spoken word recognition such as the LNT and MLNT may be one important predictor of a child's ability to acquire spoken language (Kirk et al, 1998).

Development of perception of words/lexicon in children:

The concept of similarity neighbourhoods has been used to provide important insights into the acquisition of words and the development of the lexicon in young children. Since NAM makes explicit claims about the importance of factors such as lexical discrimination and frequency biases, the model has enabled researchers and clinicians to view spoken word recognition not only from the perspective of the fairly low-level mechanisms involved in hearing and speech perception, but also in the broader context of perceptual and memory processes that also subserve the recognition process. The model has provided evidence that spoken word recognition entails much more than the recognition of the individual phonetic segments that comprise words. Thus, when evaluating individuals with hearing impairment, the model emphasizes that simple tests of speech pattern discrimination and phonetic feature discrimination will grossly underestimate the complex task that faces hearing impaired and normal listeners in understanding spoken words in naturalistic settings.

By incorporating recent insights and motivations from principled, theoretically based research on spoken word recognition, this test should prove invaluable in assessing the full range of processes necessary for recognizing spoken words in normal and in those with hearing impairment.

Thus, NAM provides a new theoretical framework for understanding the complex processes involved in recognizing spoken words among a variety of paediatric and adult normal and clinical populations. The model represents a significant advance in our understanding of how words are represented in the lexicon and how listeners gain access to this structural information. As a consequence, NAM should help basic researchers and clinicians in understanding and evaluating the complex processes involved in the recognition of spoken words and processing of spoken language.

Method

The study was carried out in two phases. The first phase involved the development of the Lexical Neighbourhood Test in Kannada for children aged 6 to 8 years. In the second phase, the developed material was administered on normal hearing children and children with hearing impairment using cochlear implants.

Participants:

For the development of the material (Phase I of the study), 45 different adults were involved. All the adults were fluent speakers of Kannada. Of these adults, 3 were regular school teachers and 3 were special educators. Further, the familiarity of the material was tested on ten children who were exposed to Kannada from early childhood. These children were reported to be typically developing and had no history of speech and hearing problems.

In Phase II of the study, data were collected from 30 typically developing children and 6 children with hearing impairment who used cochlear implants. All the children were exposed to Kannada from early childhood.

The typically developing children (Group I) were in the age range of 6 to 8 years and were exposed to Kannada from early childhood. Their AC and BC thresholds were within 15 dB HL in the frequencies from 250 Hz to 8000 Hz and 250 Hz to 4000 Hz respectively. Their speech identification scores were 90% or higher at 40 dB SL (ref: PTA) in both ears on the speech identification tests for Kannada speaking children (Vandana, 1998). They had bilateral A-type tympanograms with acoustic reflexes present at 90 dB HL in both ears at 500 Hz, 1000 Hz and 2000 Hz. In addition, it was ensured that they had no history of any speech, language or hearing problem as well as no otologic / neurologic problems. They had no illness on the day of testing.

The children using Nucleus cochlear implants (Group-II) were tested using their device in the prescribed settings for everyday use. Of them, 3 used CP 810 sound processor, 2 used Freedom sound processor and 1 used Sprint processor. All the participants used their device regularly for at least one year. Their aided audiogram was within the speech spectrum. The children had a language age of at least 6 years, as evaluated using the Kannada Language Test (UNICEF funded project, 1990) with clear speech, with limited number of misarticulation.

Testing Environment:

All the testing was carried in a sound-treated suite. The noise levels were maintained within permissible limits, as per ANSI S3.1- 1991.

Instrumentation:

A calibrated two channel diagnostic audiometer, ORBITER-922, version-2 coupled with headphones (TDH-39), bone vibrator (B-71) and sound-field speakers were used to estimate the pure-tone thresholds and speech identification abilities. A calibrated middle ear analyzer, GSI Tympstar version-2 was used to carryout immittance tests. A computer with Adobe Audition (version 1.5) software was utilized to record and present the speech tests.

Procedure:

Phase I – *Procedure for development of the material:*

The development of the material involved three steps. The three steps included determining the familiarity of words that were considered to be in the vocabulary of 6 year old children; checking the lexical density of the familiar words; and determining the frequency of occurrence of the familiar words.

Initially, a list of words that were considered to be in the vocabulary of children aged 6 years was made. The words were selected from age appropriate print material. Additionally, 15 adults who were exposed to Kannada since childhood were asked to make lists of words which they thought would be present in the vocabulary of children aged 6 years. The words from the print material and the 15 adults were pooled into a single list by omitting the common words. Thus, 550 words were obtained and the familiarity of these words was checked on 10 children aged 6 years. A word was considered highly familiar only if the children were able to describe its meaning. Words which could be described correctly by more than 80% of the children were included for further steps in the construction of the test. Of the 550 words, 230 words were found to be highly familiar.

The lexical density of the 230 words was calculated by determining the number of lexical neighbours for each word. This was done by determining the number of words that could be formed by adding, deleting, or substituting one phoneme at a time from the target word. To carry out this task, 12 adults who were educated in Kannada from early childhood and who spoke the language fluently were considered. They were instructed to construct as many lexical neighbours as possible for each of the 230 words by making use of the procedure to calculate the same. Later, the responses from the 12 participants were pooled into a single list by eliminating the words that were repeated by the different participants. The lexical neighbourhood density ranged from 0 – 15. Those words that had 3 and less than 3 neighbours were categorized to have a 'sparse neighbourhood' and those words which had more than 3 neighbours were considered to have a 'dense neighbourhood'. This cut-off value was selected since it approximated the value recommended by Kirk, Pisoni and Osberger (1995).

Further, the frequency of occurrence of the 230 words was determined by calculating the number of times each of the words occurred in text books / story books used by children in the age range of 6-8 years. The text material had as many as 507 pages and 24,980 words. The frequency of occurrence of each of the words in the text material was calculated manually. Since the word count was done manually it was calculated separately by two adults who read Kannada fluently. This was done to verify the accuracy of the word count. The frequency of occurrence was noted to range from 1 to 282. The words were then divided into two groups. Those words that occurred more than 6 times in the text material were classified as 'frequently occurring words' and those which occurred 6 or less were classified as 'infrequently occurring words'. Six was taken as the cut-off point as this value divided the words into half.

Based on the frequency of occurrence and lexical density, the words were categorized as 'lexically easy' and 'lexically hard' words. The lexically 'easy' words had 'more frequently occurring' words with 'sparse neighbourhood'. The lexically 'hard' words had 'less frequently occurring' words with 'dense neighbourhood'.

Thus, two word lists containing 40 words each were constructed taking into account the lexical density as well as the frequency of occurrence of the words. Each list consisted of equal number of 'hard' and 'easy' words, i.e., 20 easy words and 20 hard words which were randomized (Appendix).

Recording of developed word-lists:

The developed word-lists were recorded by a fluent Kannada speaker. It was ensured that the fundamental frequency of the speaker was within normal limits as measured on the Vaghmi software. The recorded material was edited and scaled using Adobe Audition software to ensure that the intensity of all sounds were similar. The recording was done using a sampling rate of 44.1 kHz and 32-bit analogue-to-digital converter. A directional boom microphone, placed 6 cm from the mouth of the speaker and connected to a computer was used for the recording. An inter-stimulus interval of 4 seconds was inserted between word pairs to obtain the response from the listeners. A 1 kHz calibration tone was inserted prior to each list. The developed material was subjected to a goodness test. This was done on 10 adults to ensure that the recording was clear. All the recorded words were found to be intelligible by 90% of these adults.

Phase II - ***Administration of the developed test material:***

Administration on normal hearing children:

The recorded stimuli were played using Adobe Audition (version 1.5) which was loaded on a computer. The output from the computer was routed to sound field speakers via a diagnostic audiometer. The loud speaker was placed at 0^0 azimuth at 1 meter distance from the head of the listener. Prior to the presentation of the stimuli, the 1 kHz calibration tone was used to adjust the VU meter deflection of the audiometer to ‘0’. The stimuli were presented in a sound-field condition at 40 dB SL (ref PTA). The participants were instructed to repeat what they heard. To ensure that they understood the instructions, they first listened to orally presented practice items that were not a part of the test items. Following this, they were presented the recorded test items. Half of the children were presented with list 1 first and the other half received list 2 first. This was done to eliminate the list order effect. The verbal outputs of the participants were noted by the tester on a response sheet which was later scored.

Administration on children with hearing aids / cochlear implants:

The children with hearing impairment were tested with their cochlear implants using their preferred stable map. Children using Nucleus cochlear implants were tested using the 'everyday' pre-processing strategy. The procedure followed was similar to that used to evaluate the normal hearing children. The verbal output of the participants was audio recorded and also noted by the tester on a response sheet. The response of children who had misarticulations were scored correct if the stimulus and their verbal output corresponded with the findings of an articulation test that had earlier been administered on them.

Scoring:

The responses of the participants were scored by the tester. Both word and phoneme scores were calculated. For calculating the word scores, a correctly identified word was assigned a score of 'one' and a wrong answer a score of 'zero'. Thus, the maximum word score was 40 for each list. Similarly, while calculating phoneme scores, every correctly identified phoneme was given a score of 'one' and a wrong phoneme a score of 'zero'. For list-1 the maximum phoneme score was 174 and for list-2 it was 168.

Statistical analyses:

The data obtained from the 30 typically developing children and 6 children with hearing impairment were analysed using Statistical Package for Social Sciences

(SPSS) software version 18. Initially, mixed ANOVA was carried out to study the main effects and the interaction between the variables for group I (children with normal hearing). Further analysis using paired t-test or Wilcoxon signed rank test was done to study the effect of lexical difficulty (easy words vs. hard words) and effect of word lists (inter-list equivalency). The performance of the children with hearing impairment using cochlear implants was analysed using Wilcoxon signed rank test. Later, the performance of the two groups was compared and analysed using Mann-Whitney U test.

Results and Discussion

The responses of 30 normal hearing children aged 6 to 8 years and 6 children with hearing impairment using cochlear implants on the developed Lexical Neighbourhood Test in Kannada are discussed. The results of the two groups of participants are discussed separately. The data were analysed using Mann Whitney U test, paired-t test or Wilcoxon Signed Rank test to:

- Compare the scores obtained by two sub-groups of normal hearing children, divided based on their ages (6 to 6; 11 years and 7 to 8 years).
- Compare the performance of the normal hearing children across the two developed lists in order to check the equivalence of the two lists,
- Compare the normal hearing children on the 'easy' and 'hard' words,
- Compare the performance of the children with hearing impairment across the two developed lists,
- Compare the children with hearing impairment on the 'easy' and 'hard' words,
- Compare the two groups of participants (normal hearing children & children with hearing impairment using cochlear implants) on the developed material.

I. Performance of typically developing children (group I):

To study the main effects and the interaction between the variables, mixed 2-way repeated measure ANOVA (2 lists x 2 word types x 2 age groups) was carried out. The results of the mixed ANOVA revealed a significant interaction between the list, word type and age [$F(1, 28) = 3.094$, $p < 0.05$] and also between the list and word type [$F(1, 28) = 0.674$, $p < 0.05$]. However, there was no significant interaction between type and age [$F(1, 28) = 1.674$, $p > 0.05$] and between list and age [$F(1, 28) = 0.916$, $p > 0.05$]. The results of the effect of age, list and word type are provided below.

Effect of Age:

The effect of age was determined by comparing the word scores of the two age sub-groups (6 to 6; 11 years and 7 to 8 years) on the easy and hard words for the two lists. Table 1 gives the mean, minimum, maximum and standard deviation (SD) values for the two age groups. As can be seen from the table, the scores were slightly higher for the older age group compared to the younger group for both easy and hard words on the two lists. However, the mixed ANOVA indicated there was no significant difference between the two age groups [$F(1, 28) = 2.754$, $p > 0.05$].

The effect of age was also determined by comparing the phoneme scores of the two age sub-groups on the easy and hard words. Table 2 gives the mean, minimum, maximum and S.D values for the two age groups. To see if there was difference between the two age groups for the phoneme scores, Mann Whitney U test was administered. This non-parametric test was administered since the scores had to be converted to percentage scores due to the unequal raw phoneme scores across the two lists / word-type. The analysis revealed that there was no significant difference for phoneme scores between the two age groups for easy words ($Z = 0.269$, $p > 0.05$), hard words ($Z = 1.788$, $p > 0.05$) as well as total scores ($Z = 1.101$, $p > 0.05$).

Table 1: *Mean and Standard Deviation (SD) of the word scores (easy words, hard words and the total word scores) for the two age groups.*

Age groups		**List 1**			**List 2**		
		***Easy**	***Hard**	**#Total**	***Easy**	***Hard**	**#Total**
6-6;11 yrs N = 15	Mean	19.27	17.33	36.6	19.47	18.27	37.73
	Min	17	15	34	18	15	35
	Max	20	20	40	20	20	40
	SD	0.88	1.45	1.96	0.74	1.34	1.67
7-8 yrs N = 15	Mean	19.40	18.47	37.87	19.73	18.53	38.27
	Min	17	15	34	19	15	34
	Max	20	20	40	20	20	40
	SD	0.83	1.46	2.03	0.46	1.36	1.58

Note: **Maximum scores for easy and hard words = 20; #Maximum Total score = 40*

Table 2: *Mean and Standard Deviation (SD) of the percentage phoneme scores (easy words, hard words and the total word scores) for the two age groups*

Age groups		**List 1**			**List 2**		
		Easy	**Hard**	**Total**	**Easy**	**Hard**	**Total**
6-6;11 yrs N = 15	Mean	98.85	96.46	97.78	99.20	97.99	98.46
	Min	94.55	93.83	94.83	95.18	94.19	95.86
	Max	100.00	100.00	100.00	100.00	100.00	100.00
	SD	1.70	1.86	1.45	1.34	1.55	1.16
7-8 yrs N = 15	Mean	99.14	97.72	98.47	99.52	98.30	98.90
	Min	96.77	92.89	95.98	97.59	94.19	96.45
	Max	100.00	100.00	100.00	100.00	100.00	100.00
	SD	1.09	2.33	1.51	0.76	1.58	1.00

The finding of the present study regarding the performance of the two age groups was similar to that of Liu et al. (2011). They studied the effect of age using the standardized Chinese version of LNT on children aged 5.0 to 5;10 years and 6.0 to

6;11. The finding of the present study and that of Liu et al. indicated that speech identification abilities of children for stimuli such as the LNT reached its peak value by a younger age. Due to a ceiling effect, with increase in age there was no further improvement in speech recognition. This probably occurred in the both the studies since the test stimuli were derived from speech materials meant for children in the younger age. While in the present study the stimuli were derived from material for the younger age group (6 to 6;11 years), in the study by Liu et al. it was derived from children younger (3 to 5 years) than their youngest age group (5.0 to 5;10 years). This could have lead to the lack of statistically significant differences between the age groups. Thus, for the Kannada LNT, children as young as 6 years can be expected to perform similar to older children.

Since the mixed ANOVA results for word scores and Mann Whitney U test for phoneme scores revealed no significant age effect, the data obtained for the two age groups were combined for further analysis. This was done while determining the effect of inter-list equivalency and lexical difficulty.

Inter-list equivalency:

To compare the performance of the normal hearing children across the two lists developed, the mean and the SD of both easy and hard words were analysed. In both list 1 and list 2, the mean word scores were similar for easy words (19.33 & 19.60 respectively), hard words (17.90 & 18.40 respectively) and total scores (37.23 & 38.00 respectively) as evident from Table 3. Similar to the word scores, the mean phoneme scores were similar for the easy words (99.00 & 99.36 respectively), hard words (97.09 & 98.14 respectively) and total scores (98.12 & 98.68 respectively) as seen in Table 4.

Mixed ANOVA results revealed that there was no significant main effect for list [$F(1, 28) = 4.003$, $p > 0.05$]. Further, to confirm if the two lists were equivalent statistically for easy words, hard words and for total word scores, paired-t test was carried out. This further analysis also revealed that there was no significant difference between the two lists for easy words ($t = 1.161$, $p > 0.05$), hard words ($t = 1.675$, $p > 0.05$) and also for the total scores ($t = 2.004$, $p > 0.05$). Similarly, to confirm list equivalency for the phoneme scores, Wilcoxon Signed Rank test was carried out. Once again, the results revealed that there was no significant difference between two lists for the easy words ($Z = 1.085$, $p > 0.05$), hard words ($Z = 2.585$, $p > 0.05$) as well as the total scores ($Z = 1.590$, $p > 0.05$).

As the two lists were found to be equivalent, it is recommended that they can be used alternatively during any assessment in order to avoid any word familiarity effect. The lists can be used interchangeably irrespective of whether word or phoneme scores are being calculated.

Table 3*: Mean and SD of word scores (easy words, hard words and the total word scores) for 30 normal hearing individuals.*

List	**Word type**	**Mean**	**SD**	**Range**	
				Min	**Max**
List 1	*Easy	19.33	0.84	17	20
	*Hard	17.90	1.54	15	20
	#Total	37.23	2.06	34	40
List 2	*Easy	19.60	0.62	18	20
	*Hard	18.40	1.33	15	20
	#Total	38.00	1.62	34	40

Note: **Maximum scores for easy and hard words = 20; #Maximum Total score = 40*

Table 4: *Mean and SD of percentage phoneme scores (easy words, hard words and the total word scores) for 30 normal hearing individuals.*

List	**Word type**	**Mean**	**SD**	**Range**	
				Min	**Max**
List 1	Easy	99.00	1.41	93.55	100
	Hard	97.09	1.67	92.89	100
	Total	98.12	1.50	94.83	100
List 2	Easy	99.36	1.08	95.18	100
	Hard	98.14	1.55	94.19	100
	Total	98.68	1.09	95.86	100

Effect of lexical difficulty on speech identification scores:

The effect of lexical difficulty was analyzed by comparing the scores obtained for lexically easy and lexically hard words. Table 3 shows the mean and SD values of word scores for easy and hard words for the two lists. From the table it is evident that the mean scores for hard words were lesser than that of easy words. Mixed ANOVA results revealed a significant main effect for word type [F (1, 28) = 46.43, p < 0.001] with lists and age groups combined. Thus, for further analysis, paired–t test was done. It was found that there was a significant difference between easy and hard words for both list 1 (t = 5.68, p < 0.001) and list 2 (t = 5.07, p < 0.001).

Similarly, Table 4 shows the mean and SD values of the phoneme scores for easy and hard words for the two lists. It can be seen from the table that the mean scores for hard words were lesser than that of easy words. Wilcoxon signed rank test revealed that there was a statistically significant difference between the scores obtained for the easy and hard words. This was evident in both list 1 (Z = 3.69, p < 0.001) and in list 2 (Z = 3.18, p < 0.001).

Earlier reported studies had also observed that easy words were easier to perceive than hard words. Thus, the finding of the current study are consistent with what has been found in the English LNT (Kirk, Osberger & Pisoni, 1995; Dirks, Takayana & Moshfeqh, 2001) and in LNT of other languages (Yang & Wu, 2005; Patro & Yathiraj, 2010; Singh, 2010; Liu et al., 2011). As seen in the other studies, the children in the present study found more frequently occurring words with sparse neighbourhoods to be easier to identify. Liu et al. (2011) opined that repeated stimulations with frequently occurring words might have strengthened their memory of the words and consolidate the words in the lexicon compared to the less frequently occurring words. Furthermore, the sparser neighbourhood density might have facilitated retrieval of the 'easy' words as a result of a 'top-down' process. Therefore, children have better mastery of the 'easy' words than the 'hard' words as observed by Liu et al. (2011).

The finding of the present study indicates that the developed material does represent different lexical difficulties. Hence, it can be used to tap the perceptual differences in children and can be used as a valid clinical tool in examining perceptual processes underlying spoken word recognition in Kannada language.

II. Performance of children with hearing impairment using cochlear implants (group II):

The mean and the SD values for the easy and hard words for the 6 participants with hearing impairment using cochlear implants are given in Table 5 for the word scores and Table 6 for the phoneme scores. Similar to the performance of normal hearing group, the children with hearing impairment also performed better on the easy words compared to the hard words. This was observed for both the lists.

Table 5: *Mean and Standard Deviation (SD) of the word scores (easy words, hard words and the total word scores) for 6 children with hearing impairment.*

List	Word type	Mean	S.D	Range	
				Min	Max
List 1	*Easy	15.83	0.98	14	17
	*Hard	12.50	1.51	10	14
	#Total	28.33	2.42	24	31
List 2	*Easy	15.83	1.17	14	17
	*Hard	12.33	1.63	11	15
	#Total	28.17	2.48	25	32

Note: **Maximum scores for easy and hard words = 20; #Maximum Total score = 40*

Table 6: *Mean and Standard Deviation (SD) of the phoneme percentage scores (easy words, hard words and the total word scores) for 6 children with hearing impairment.*

List	Word type	Mean	S.D	Range	
				Min	Max
List 1	Easy	90.32	3.85	83.87	94.62
	Hard	87.65	4.06	80.25	91.36
	Total	89.08	3.86	82.18	93.10
List 2	Easy	91.57	2.80	86.75	93.98
	Hard	87.02	3.07	83.74	90.70
	Total	88.76	2.97	85.21	92.30

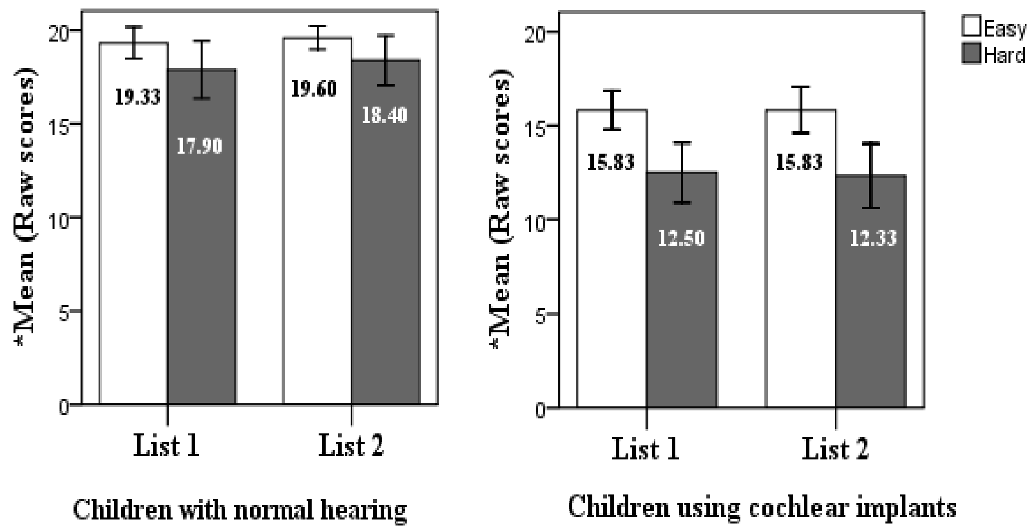
Further, Wilcoxon Signed Rank test was done for both word scores and phoneme scores to see if the difference between the easy and the hard words were statistically significant. It was found that there was a significant difference between easy and hard words for list 1 ($Z = 2.232$, $p < 0.05$) and for list 2 ($Z = 2.236$, $p < 0.05$) for word scores. Similarly, for phoneme scores it was found that there was a significant difference between easy and hard words for list 1 ($Z = 2.201$, $p < 0.05$) and for list 2 ($Z = 2.201$, $p < 0.05$).

In addition, Wilcoxon Signed Rank test was also done for both word scores and phoneme scores to see whether there was any difference between the scores obtained across the two lists. The results showed that there was no significant difference between the two lists for the easy words ($Z = 0.04$, $p > 0.05$), hard words ($Z = 0.447$, $p > 0.05$) and the total scores ($Z = 0.378$, $p > 0.05$) for word scores. Likewise, with the phoneme scores there was no significant difference between the two lists for the easy words ($Z = 0.526$, $p > 0.05$), hard words ($Z = 0.949$, $p > 0.05$) and the total scores ($Z = 0.524$, $p > 0.05$). Similar performance across the lists suggests that the two lists developed are equivalent even when used with children using cochlear implant.

This finding of difference in the performance of easy and hard words in cochlear implant users is in consonance with previous studies (Kirk et al., 1995; Kirk, Eisenberg, Martinez & McCutcheon, 1998; Dirks et al., 2001; Yang & Wu, 2005; Yuen et al., 2008; Wang, Wu & Kirk, 2010 & Liu et al., 2011). It suggests that cochlear implant users also utilised their lexical knowledge in word recognition tasks. Kirk et al. (1995) reported that despite a hearing loss and with the degraded sensory input provided via the cochlear implant, their subjects were sensitive to the acoustic-phonetic similarity among the test words. Kirk also reported that though these children have limited vocabularies, they appear to organize words into similarity neighbourhoods in long-term memory, and use this structural information in recognizing isolated words. In a similar manner, the children using cochlear implants in the present study were also able to utilise strategies in a comparable way as that of normal hearing children. This could have lead to them perceive easy and hard words differently.

III. Comparison of performance of children with normal hearing and children with hearing impairment using cochlear implants:

The mean and SD for the word scores and phoneme scores are provided in Figure 1 and Figure 2 respectively. The figures present information of the normal hearing individuals as well as of those with hearing impairment. For both the groups, the mean scores for children with normal hearing were greater than for the children with hearing impairment using cochlear implants.



Note: * *Maximum score is 20*

Figure 1: Mean easy and hard word scores for children with normal hearing and for children with hearing impairment using cochlear implants.

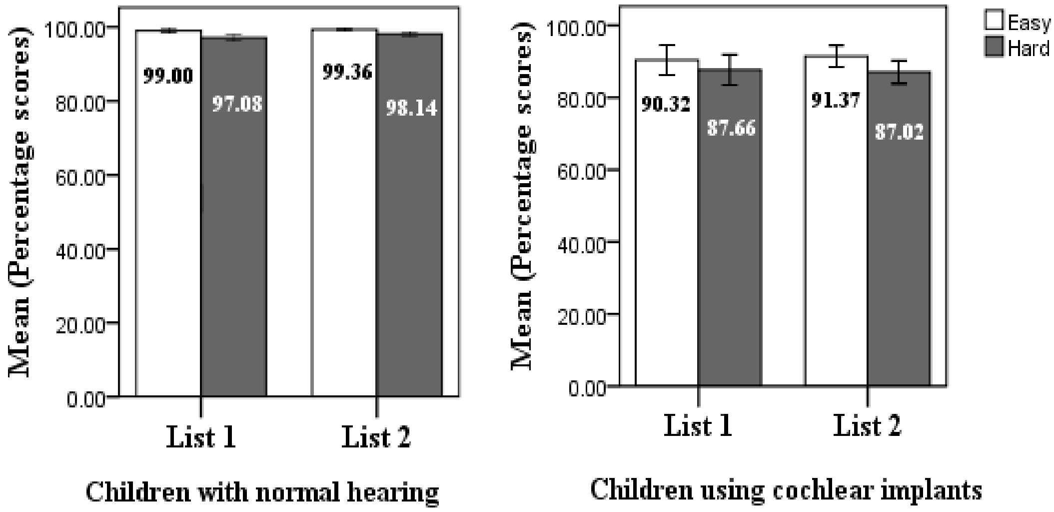


Figure 2: Mean percentage phoneme scores (for easy and hard words) for children with normal hearing and for children with hearing impairment using cochlear implants.

Mann Whitney U test was used to test the significance of difference between group I and group II for word scores. The results showed that for both the lists there was significant difference between the two groups. This was observed for both easy ($Z = 4.006$, $p < 0.001$) and hard words ($Z = 3.885$, $p < 0.001$) in list 1. Similar findings were obtained in list 2 for the easy ($Z = 4.225$, $p < 0.001$) and hard words ($Z = 3.854$, $p < 0.001$).

To compare the performance of 2 groups on easy and hard words for phoneme scores, Mann Whitney U test was administered which also revealed significant difference between group I and group II. This was observed for both easy ($Z = 3.947$, $p < 0.001$) and hard words ($Z = 3.858$, $p < 0.001$) for list 1. Similar findings were obtained for list 2 for the easy ($Z = 4.163$, $p < 0.001$) and hard words ($Z = 3.884$, $p < 0.001$).

The above finding is in consonance with previous research by Wang et al. (2010) who studied cochlear implant users and by Patro and Yathiraj (2010) who studied hearing aid users. In both the studies, children with hearing impairment performed significantly poorer than that of normal hearing children on both easy and hard words. Patro and Yathiraj (2010) reported that this poor performance may be because the listening device worn by them was not able to compensate totally for their hearing deficit.

Thus, from the present study the following findings can be inferred:

- There was no significant difference in the performance of children with normal hearing between the two age groups considered.
- There was a significant effect of lexical difficulty for both the groups (children with normal hearing and for children with hearing impairment using cochlear implants). Both groups performed better on the lexical easy words and poorer on the lexical hard words.
- There was no significant difference between the two lists developed thus confirming the inter-list equivalency.
- There was a significant difference between the performances of children with normal hearing and children with hearing impairment using cochlear implants on both the lists for easy and hard words.
- Similar trend of findings were seen in the performance for the word scores and phoneme scores for both the groups and for all the parameters.

Summary and Conclusions

Several word identification tests are available to determine the auditory perceptual difficulties of children with hearing impairment. At one extreme are simple tests such as the pattern perception test (Moog & Geers, 1990; Ross & Lerman, 1979; Elliot & Katz, 1980; Prakash, 1999; Begum, 2000; Chowdry, 2003; Jijo & Yathiraj, 2008). On the other extreme are phonemically-balanced open-set word tests (Haskins, 1949; Bench, Knowal & Bamford, 1979; Robbins, Renshaw & Osberger, 1995) that can be made more difficult by adding distortion such as noise. For children who are in the process of developing speech and language, there is a need for a speech identification test that is neither too easy nor too difficult. The Lexical Neighbourhood Test (LNT), developed by Kirk, Pisoni, and Osberger (1995) has been found to serve as one such test. This test permits the evaluation of the auditory perceptual difficulty of children with hearing impairment before they get to the stage where they can be evaluated with PB words.

Kirk et al. (1995) reported that the LNT assessed spoken word recognition in order to reveal the perceptual processes employed by children, especially among those using cochlear implants. The LNT test items were formed based on the frequency of occurrence of words in the language (word frequency) and the number of phonetically similar words surrounding the word (lexical density). In view of the need for language specific tests, the LNT has been developed in different languages such as Mandarin (Yang & Wu, 2005), Cantonese (Yuen et al., 2008) and Chinese (Liu et al., 2011). In India it is currently available only in Indian English (Patro & Yathiraj, 2010) and in Hindi (Singh, 2010). However, it is not available in Kannada and hence there is a need to develop such a test in Kannada.

The aim of the study was to develop a Lexical Neighbourhood test in Kannada for children aged 6 to 8 years, who were divided into two age groups (6 to 6; 11 years and 7 to 8 years). The study also aimed to check the utility of the developed test on the target group and in children with hearing impairment using cochlear implants; and check if there was any difference in performance between the two age subgroups.

The study was carried out in two phases. The first phase involved the development of the Lexical Neighbourhood Test in Kannada for children aged 6 to 8 years. In the second phase, the developed material was administered on normal hearing children and children with hearing impairment using cochlear implants.

The development of the material involved determining the familiarity of words that were in the vocabulary of 6 year old children; checking the lexical density of the familiar words; and determining the frequency of occurrence of the familiar words. Based on the frequency of occurrence and lexical density, the words were categorized as 'lexically easy' and 'lexically hard' words. The lexically 'easy' words had 'more frequently occurring' words with 'sparse neighbourhood'. The lexically 'hard' words had 'less frequently occurring' words with 'dense neighbourhood'. Thus, two word lists containing 40 words each were constructed taking into account the lexical density as well as the frequency of occurrence of the words. Each list contained 20 easy words and 20 hard words which were audio recorded in a random order.

The developed test material was administered on children with normal hearing and children with hearing impairment using cochlear implant. The participants were instructed to repeat what they heard and the verbal outputs of the participants were noted by the tester on a response sheet. The responses were later scored for both word scores and phoneme scores.

The data obtained from the 30 typically developing children and 6 children with hearing impairment were analysed using Statistical Package for Social Sciences (SPSS) software version 18. Initially, mixed ANOVA was carried out to study the main effects and the interaction between the variables and further analysis using paired t-test or Wilcoxon signed rank test was done wherever necessary.

There was no significant difference between the *two age groups* (6 to 6; 11years and 7 to 8 years) of normal hearing children, measured using mixed ANOVA. This implied that, for the Kannada LNT, children as young as 6 years can be expected to perform similar to older children aged 8 years.

Paired-t test revealed no significant difference between the two lists developed thus confirming the *inter-list equivalency*. Hence, the two lists can be used alternatively during any assessment in order to avoid any word familiarity effect. Performance of children using cochlear implants were also found to be equivalent across the two lists as per Wilcoxon signed rank test. This finding substantiated the inter-list equivalency of the developed lists.

There was a significant effect of *lexical difficulty* on both the groups (children with normal hearing and for children with hearing impairment using cochlear implants). This was established based on the findings of paired-t test and Wilcoxon signed rank test respectively. This probably occurred because easy words with more frequency of occurrence of word might have strengthened the memory of the words. Also with sparser neighbourhood density, words might have been retrieved more easily as a result of a ‘top-down’ process (Liu et al., 2011), resulting in better performance for easy words than hard words in these children.

There was a significant difference between the performances of children with normal hearing and children with hearing impairment using cochlear implants on both the lists for easy and hard words when Mann Whitney U test was carried out. The poorer performance by the children with hearing impairment when compared to that of typically developing children has been attributed to the limited utility of the listening device worn by them (Patro & Yathiraj, 2010). Thus, the test indicated that the device worn by the children was not able to compensate totally for their hearing deficit.

Findings, similar to the above word scores were also observed for the percent phoneme scores that were analysed using Non-parametric tests like Mann Whiney U test and Wilcoxon signed rank test. Thus, irrespective of whether word scores or phoneme scores were calculated, similar trend of findings were seen across age groups, lists, and children with and without hearing impairment.

Implications of the present study:

- The material developed can be used as a valid clinical tool for assessing the speech perception abilities in children.
- The test can be administered on those children who perform well on simple closet set tests but perform poorly on open set PB word tests, as the difficulty of the test lies in between these two extremes of perceptual difficulty.
- It can be helpful in selection of appropriate listening devices.
- The test may provide guidelines in planning the therapy effectively.

- Also, the test may help in monitoring the progress of a child overtime thus helping to evaluate the effectiveness of any therapy approach/ procedure.
- As the developed material represented different lexical difficulties, it can be used to tap the perceptual differences in children and can be used as a valid clinical tool in examining perceptual processes underlying spoken word recognition in Kannada language.

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Appendix

LNT- List 1

Sl no	Words		Easy/ Hard	Sl no	Words		Easy/ Hard
1.	ಊಟ	/u:Ta/	Easy	21.	ಮಗು	/magu/	Easy
2.	ಕೊಳೆ	/koLe/	Hard	22.	ಬಳೆ	/baLe/	Hard
3.	ಇಷ್ಟ	/ishTa/	Hard	23.	ಪ್ರಾಣಿ	/pra:Ni/	Easy
4.	ಐದು	/aidu/	Hard	24.	ಮೂಗು	/mu:gu/	Hard
5.	ಕಾಗೆ	/ka:ge/	Easy	25.	ರೊಟ್ಟಿ	/roTTi/	Easy
6.	ಹಿಡಿ	/hiDi/	Hard	26.	ನಡಿ	/naDi/	Hard
7.	ಕುರ್ಚಿ	/kurchi/	Easy	27.	ಸೂರ್ಯ	/su:rya/	Easy
8.	ಹಲ್ಲು	/hallu/	Hard	28.	ಚಾಕು	/cha:ku/	Hard
9.	ಕೋತಿ	/ko:ti/	Easy	29.	ಶಕ್ತಿ	/shakti/	Easy
10.	ಸಾರು	/sa:ru/	Hard	30.	ಕರಿ	/kari/	Hard
11.	ಕಷ್ಟ	/kashTa/	Easy	31.	ಸ್ವಲ್ಪ	/swalpa/	Easy
12.	ವಾರ	/va:ra/	Hard	32.	ಕೂಗು	/ku:gu/	Easy
13.	ಚಂದ್ರ	/chandra/	Easy	33.	ಶಿಕ್ಷೆ	/shikshe/	Easy
14.	ಲೋಟ	/lo:Ta/	Hard	34.	ಕಚ್ಚು	/kachchu/	Hard
15.	ನಿಮ್ಮ	/nimma/	Easy	35.	ರಾಜ	/ra:ja/	Easy
16.	ಮುಳ್ಳು	/muLLu/	Hard	36.	ಕಾಸು	/ka:su/	Hard
17.	ತಾತ	/ta:ta/	Easy	37.	ಹಬ್ಬ	/habba/	Easy
18.	ಬೀಳು	/bi:Lu/	Hard	38.	ಆರು	/a:ru/	Hard
19.	ಬಸ್ಸು	/bassu/	Easy	39.	ಹೊಟ್ಟೆ	/hoTTe/	Easy
20.	ಬಾಯಿ	/ba:yi/	Hard	40.	ಅನ್ನ	/anna/	Hard

Appendix

LNT- List 2

SI. no	Words		Easy/ Hard	SI. no	Words		Easy/ Hard
1.	ಇದೆ	/ide/	Easy	21.	ಬಣ್ಣ	/baNNa/	Easy
2.	ಮಾತ್ರೆ	/ma:tre/	Hard	22.	ಮಳೆ	/maLe/	Hard
3.	ಒಬ್ಬ	/obba/	Easy	23.	ಟೋಪಿ	/To:pi/	Hard
4.	ಬಾಲು	/ba:lu/	Easy	24.	ಮಣ್ಣು	/maNNu/	Hard
5.	ಕಪ್ಪೆ	/kappe/	Hard	25.	ಯಾಕೆ	/ya:ke/	Easy
6.	ಹುಳಿ	/huLi/	Hard	26.	ನಂದು	/nandu/	Hard
7.	ಕಸ	/kasa/	Easy	27.	ಸೇಬು	/se:bu/	Easy
8.	ಹಳ್ಳಿ	/haLLa/	Hard	28.	ಜಾರು	/ja:ru/	Hard
9.	ಗಿಡ	/giDa/	Easy	29.	ಶಾಲೆ	/sha:le/	Easy
10.	ಸಾಕು	/sa:ku/	Hard	30.	ಕಡ್ಡಿ	/kaDDi/	Hard
11.	ಕೋಪ	/ko:pa/	Easy	31.	ಸುತ್ತ	/sutta/	Easy
12.	ರಜ	/raja/	Hard	32.	ಕಾಳು	/ka:Lu/	Hard
13.	ಚಿತ್ರ	/chitra/	Easy	33.	ಸಿಂಹ	/simha/	Easy
14.	ಬನ್ನಿ	/banni/	Easy	34.	ಕಪ್ಪು	/kappu/	Hard
15.	ಜಾಣ	/ja:Na/	Easy	35.	ರಾತ್ರಿ	/ra:tri/	Easy
16.	ಮುತ್ತು	/muttu/	Hard	36.	ಕಾಯಿ	/ka:yi/	Hard
17.	ತುಂಬ	/tumba/	Easy	37.	ಹಸು	/hasu/	Easy
18.	ಬಿಚ್ಚು	/bichchu/	Hard	38.	ಏಳು	/e:Lu/	Hard
19.	ಬೇಕು	/be:ku/	Easy	39.	ಮೊಲ	/mola/	Easy
20.	ಬಾವಿ	/ba:vi/	Hard	40.	ಅಲ್ಲಿ	/alli/	Hard