# The Lexical Neighbourhood Test: An Indian-English Version for Children

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## Abstract

*The study involved the development of a Lexical Neighbourhood Test in Indian-English for children. The developed test containing 2 lists, each having 10 lexically easy words and 10 lexically hard words, were administered on 30 normal hearing children aged 6 to 8 years. In addition, 5 children with hearing impairment, using amplification devices, were also studied. Wilcoxon sign rank test was done to study the inter-list equivalency and the Mann-Whitney's U test was done to check the effect of age on the developed 'The Lexical Neighbourhood Test in Indian-English'. No significant inter-list differences were observed for both the lexically easy and lexically hard words. However, there was a significant difference between the younger (6 to 6;11 years) and older age group (7 to 8 years) for both lexically easy and lexically hard words. In addition, it was found that lexically 'easy' words (i.e., those that occurred often and had only a few words that were phonemically similar) were identified correctly more often than lexically 'hard' words (i.e., those that occurred less number of times and had many words that were phonemically similar). This was seen in both the normal hearing children and the children with hearing impairment. However, the latter group performed significantly poorer than the former group. The results demonstrated that the LNT in Indian-English provided reliable information about spoken word identification abilities of children with profound hearing loss who use amplification devices. In addition, the developed test also provided detailed information about the way children organized and accessed spoken words from long-term lexical memory.*


***Key words:*** *Lexical neighbourhood, dense words, sparse words.*

Though several speech identification tests have been developed for children (Elliot & Katz, 1980; Moog & Geers, 1990; Ross & Lerman, 1970, Rout, 1996; Vandana, 1998), these tests have been observed not to address some difficulties faced by the target population, especially those with cochlear implants and hearing aids (Cullington, 2000). It has been observed by Mukari, Ling and Ghani (2007) that children with cochlear implants performed poorly on the PB-K, a phonetically balanced test for children, as it contains words that were unfamiliar to young deaf children who typically have very limited vocabulary. Fryauf-Berstchy, Tyler, Kelsay, Gantz, and Woodworth, (1997) found it necessary to use a reduced set of PB-K test items with younger children who could not demonstrate knowledge of the vocabulary on the full-set of 50 items.

To overcome the difficulty faced with the PB-K, Kirk, Pisoni, and Osberger (1997) developed the Lexical Neighbourhood Test (LNT) to assess spoken word recognition. They claimed that the test revealed the perceptual processes employed by children, especially those using cochlear implants. The test items included more familiar and more frequently occurring words, from a language sample produced by normal hearing children aged 3-5 years. Therefore, it was assumed to represent early-acquired vocabulary.

The LNT was theoretically driven by the Neighbourhood Activation Model (NAM) by (Luce & Pisoni, 1998). It was postulated in the NAM that words were organized into neighbourhoods based on their frequency of occurrence in the language (word frequency) and number of phonetically similar words surrounding the word (lexical density). They measured the lexical density of a particular word by counting the number of lexical neighbours generated by substituting, deleting or adding one phoneme at a time. Words with many lexical neighbours were considered to have a 'dense' lexical neighbourhood, whereas those with only few lexical neighbours were considered as having a 'sparse' neighbourhood. Thus, the NAM provided a two-dimension account on how the sound pattern of words gave rise to word recognition.

It is evident that despite words being familiar, their frequency of occurrence in the language (word frequency) and number of phonetically similar words with which it could be misperceived (lexical density) needs to be considered while measuring speech identification abilities. There are several speech identification tests for children developed in India (Jijo, 2008; Mayadevi, 1974; Prakash, 1999; Begum, 2000; Rout, 1996; Swarnalatha, 1972; Vandana, 1998). These tests were developed taking into account only the familiarity of the test stimuli but did not consider word frequency and lexical density. The latter two aspects are known to provide perceptual information of different dimensions regarding the perception of speech (Kirk, Pisoni, & Osberger, 1997). This information would be

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especially useful in evaluating 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 their devices over a period of time, with or without training. Thus, there is a need to develop such a test, especially since there does not exists one in Indian-English for children.

The present study aimed to develop a lexical neighbourhood test for children speaking Indian-English having two equivalent lists. Further, the study aimed to compare the scores obtained on the developed test for the lexically easy and lexical hard words on normally hearing children across different ages. In addition, the study intended to check the difference in performance of children with normal hearing with that of children using hearing aids.

## Method

The study was done in two phases that included the development of the test material, and the administration of the developed test material on two groups of children. While one group comprised of normal hearing children, the other had children with hearing impairment using digital hearing aids.

**Development of the material**: Two major lexical properties, word frequency and lexical neighbourhood density, were taken into consideration while developing the stimuli. Word frequency in Indian-English was determined by calculating the number of times a particular word occurred in a large sample of print material for children. The material was selected from story books and text books meant for 6-8 year old children. The text material having as many as 268 pages and 22606 words were scanned. Seven hundred and nineteen monosyllabic words familiar to children studying in English medium schools from I to III were selected from this material. These words had been listed by the Central Institute of Indian Languages (Udaya, 2006). The frequency of occurrence of these words was calculated by using'word count' software. It was found that the frequency of occurrence of monosyllabic word frequency ranged from 1 to 189. These monosyllabic words were divided into two groups. Those words that occurred more than 15 times in the material were classified as 'frequently occurring words' and those that occurred less than 15 times were classified as 'infrequently occurring words'. This cut-off criterion was selected since approximately half of the words occurred at / above this level and the other half occurred below this level.

The lexical neighbourhood density was calculated by counting the number of neighbours that could be formed from a target word by adding, substituting, or deleting one phoneme from it. It included homophones of the target word. Five young adults who had undergone their education from early childhood in English and who also spoke the language fluently were used to calculate the lexical neighbourhood density. They were provided words that had been categorised as 'frequently occurring words' and as 'infrequently occurring words'. Using these words they were instructed to construct as many words as possible making use of the procedure to calculate the lexical neighbourhood density. The responses of the five participants were pooled to form one list. Words that were repeated by the different participants were eliminated. The lexical neighbourhood density for the given monosyllabic words ranged from 0 to 17. The words which had less than 3 neighbours were categorized as 'sparse neighbourhood' and those having more than 3 neighbours were categorized as 'dense neighbourhood'. This cut off was used since several of the words had 3 or more neighbours.

Using the above words that had taken into account the frequency of occurrence as well as the lexical density, two word lists containing 20 words each were constructed. Each list consisted of equal number of 'hard' and 'easy' words. In addition, the phoneme representation was almost similar in the two lists. The lexically 'easy' words contained more frequently occurring words with 'sparse neighbourhood' and the lexically 'hard' words contained less frequently occurring words with 'dense neighbourhood'. This categorisation was similar to that recommended Kirk et al. (1999).

The developed word-lists were recorded by a female speaker who spoke English clearly and fluently. The recording was done using a sampling rate of 44.1 kHz and 32-bit analogue-to-digital converter. The recorded material was edited and scaled using Adobe Audition software to ensure that the intensity of all the words were similar. A 5 second inter-stimulus interval was added between each word. A 1 kHz calibration tone was inserted prior to each test. A goodness test for the developed material was carried out on 10 adults to ensure the recording was proper and intelligible. A word was rerecorded if less than 90% of these participants could not identify it. The recorded words were randomized to rule out homogeneity.

**Participants:** Data were collected from children in the age range of 6 to 8 years who had studied in English medium schools for 2 to 4 years. The participants consisted of thirty children (17 males &13 females) having normal hearing. Their AC and BC thresholds were within 15 dB HL in the frequencies 250 Hz to 8000 Hz. The absence of any middle ear problem was confirmed with the presence of A-type tympanograms with acoustic reflexes present at 90 dB HL in both ears at 500 Hz, 1000 Hz and 2000 Hz. Also, their speech identification scores were 90% or higher at 40 dB SL (ref: PTA) in both ears on monosyllabic words (Rout, 1996). It was ensured that they had no history of hearing loss and no otologic / neurologic problems. On the day of testing, they had no illness.

In addition, 5 children having hearing impairment were also evaluated to determine the utility of the developed test. These children in the age range of 11 to 15 years had used digital behind the ear hearing aids for a duration of at least 3 years. All the children had a language age of at least 6 years, as evaluated using the Bankson's Language Screening Test (Bankson, 1977).

**Testing Environment**: All the tests were carried in a sound-treated dual room set-up. The noise levels were maintained within permissible limits, as per ANSI S 3.1- 1991.

**Instrumentation:** A calibrated two channel diagnostic audiometer (ORBITER 922, version-2), coupled with TDH-39 headphones, B-71 bone vibrator and sound field speakers was used to estimate the pure-tone thresholds and speech identification abilities. A calibrated middle ear analyzer (GSI-Tympstar version 2) was used to carry out immittance tests. A computer with Adobe Audition (version 2.0) software was utilized to record and present the speech tests.

**Administration of Lexical neighbourhood test:** The developed lexical neighbourhood test was presented in a sound-field condition at 40 dB SL (ref PTA). The recorded material was played using a computer, the output of which was routed through the audiometer. The participants heard the output of the audiometer through a loud speaker that was placed at $0^{o}$ azimuth, 1 meter away from the head of the listener. Prior to presentation of the stimuli, the 1 kHz calibration tone was used to adjust the VU meter deflection of the audiometer to '0'. The verbal responses of the participants were noted by the tester on a response sheet. While half the normal hearing participants heard List-1, the other half heard List-2. The selection of the list that a participant heard was randomly done.

The children with hearing impairment were evaluated while they wore their digital hearing aids in the prescribed settings. These children listened to both List-1 and List-2. As the intelligibility of their speech was not very clear, oral as well as written responses were obtained. The oral responses were transcribed by the experimenter. The scores were calculated primarily from the written responses of the children. The oral responses were used only to confirm that an incorrect written response was a true error. If a response was written wrong, but the oral response was right, the word was scored as correct.

The written responses of the participants were scored to obtain word scores and phoneme scores. While determining word scores, every correct word was given a score of one and a wrong word was given a score of zero. Similarly, while calculating phoneme scores, every correctly identified phoneme was given a score of one and a wrong phoneme was given a score of zero.

The data obtained data from the 30 children with normal hearing and 5 participants with hearing impairment were analyzed using the Statistical Package for Social Sciences (SPSS) software version 18. Initially, the data of the normal hearing group were analysed to determine the effect of lexical category on scores; effect of word lists (List-1 vs. List-2); and effect of age on the performance of both easy and hard words. Later, the performance of the children with hearing impairment using hearing aids was analysed and compared with the scores obtained by the normal hearing children.

## Results and Discussion

**The Effects of lexical properties in the normal hearing group:** The mean, standard deviation (SD) and range were obtained to check the performance of normal hearing children on lexically easy and lexically hard words. On observation of the findings of the descriptive statistics (Table 1), it was noted that the mean scores obtained for the hard words were lower than that obtained for lexical easy words. The range of scores was also larger for the hard words.

The trend in scores was also evident in the individual scores obtained by the 30 children who were evaluated. From Figure 1 it can be seen that all 30 children performed better on the lexically easy words when compared to lexically hard words. Wilcoxon sign rank test was done to see if the difference in scores on the word type were significantly different or not. The analysis revealed that there was a significant difference between the easy and hard words for both list-1 ($Z = 3.46$, $p < 0.001$) and list-2 ($Z = 3.50$, $p < 0.001$). While the former study was done using English, the latter was done using Cantonese. This indicates that the material developed in the present study does represent different lexical categories and is able to tap the perceptual differences in children with normal hearing.

*Table 1. Mean, standard deviation (SD) and range of scores for lexically easy and hard words obtained by children with normal hearing*

| List | Word type | N | Mean* | SD | Range | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| List 1 | Easy words | 15 | 18.33 | 0.98 | 17.00 | 20.00 |
| | Hard words | 15 | 15.60 | 0.99 | 13.00 | 17.00 |
| List 2 | Easy words | 15 | 18.20 | 1.20 | 16.00 | 20.00 |
| | Hard words | 15 | 15.53 | 1.18 | 14.00 | 17.00 |

*Maximum scores = 20

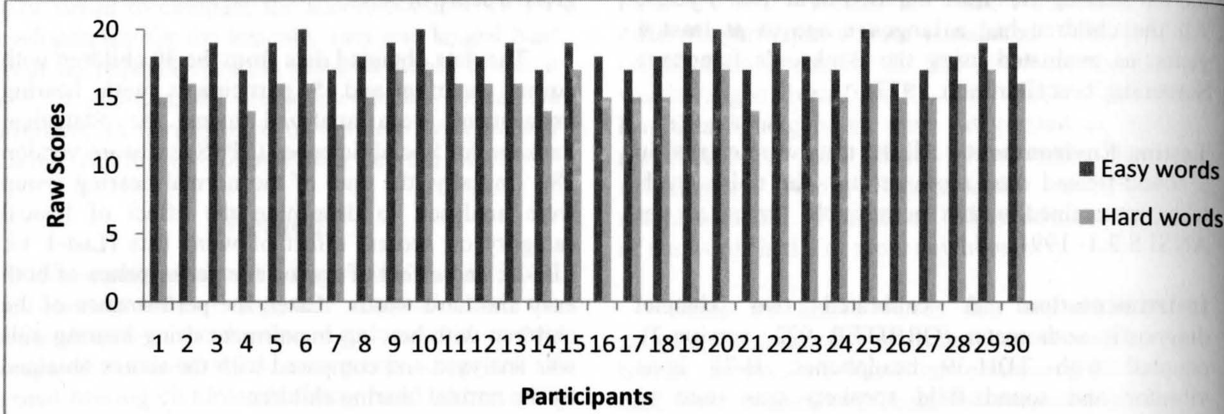


*Figure 1. Individual scores for lexically easy words and lexically hard words obtained by normal hearing children.*

**Inter-List Equivalency**: For each list, the mean and standard deviation of both lexical easy and hard were obtained for the 15 normal hearing participants. On both lists, the mean scores for lexical easy words were similar (18.33 and 18.20). Likewise, the mean scores were similar for the hard words in both lists (15.60 and 15.53). Further, the standard deviations were also similar for the two lists. This was seen for both easy and hard words.

To confirm whether the two lists were equivalent statistically, Wilcoxon sign rank test was carried out. No significant difference between list-1 and list-2 ($Z = 0.17$, $p > 0.05$) was observed. The equivalence between the two lists can be attributed to caution taken during the development of the test material. During the development of the material, across the two lists the easy and hard words were matched. In addition, the occurrence of phonemes across the two lists was also matched. This would have ensured that the two lists were equivalent.

As the two lists were found to be equivalent, they can be interchangeably used. This would be useful while determining pre and post intervention strategies on a particular child or while comparing performance across devices.

*Table 2. Mean and standard deviation (SD) for list-1 and list-2 for easy and hard words obtained by children with normal hearing*

| List | LIST – 1 | | LIST – 2 | |
|---|---|---|---|---|
| Word Type | Easy | Hard | Easy | Hard |
| Mean scores* | 18.33 | 15.60 | 18.20 | 15.53 |
| SD | 0.98 | 1.18 | 0.99 | 1.20 |

*Maximum scores = 20

**The effect of age:** The effect of age was determined after merging the data obtained from the two lists as they were found to be equivalent. This was done to increase the data points. Since half the children had listened to list-1 and the other half to list-2, the maximum possible score continued to be 20. From Table 3 it is evident that the older children (7 to 8 years) performed better than the younger children (6 to 6;11 years). This trend was seen for the easy words as well as the hard words.

*Table 3. Mean and standard deviation (SD) for younger and older children on easy and hard words with scores of list-1 and list-2 combined*

| Age groups | | Lexically Easy words | Lexically Hard words |
|---|---|---|---|
| Younger (6-6;11 yrs) N = 13 | Mean* | 17.54 | 14.77 |
| | SD | 0.78 | 0.83 |
| Older ( 7-8 yrs) N = 17 | Mean* | 18.82 | 16.18 |
| | SD | 0.95 | 0.81 |

*Maximum scores = 20

Further, Mann-Whitney's U test was done to see if the difference in scores across the age groups were significantly different or not. The analysis shed light that there was a significant difference between the younger and older age group for both lexically easy ($Z = 3.27$, $p < 0.001$) and lexically hard words ($Z = 3.60$, $p < 0.001$).

The effect of age was also analysed for each of the lists separately. The number of children in each of the groups differed. In the younger group, 6 were evaluated on list-1 and 7 were evaluated on list-2 while for the older group, 9 were evaluated on list-1 and 8 were evaluated using list-2. From the scores shown in Table 4 it is evident that older children continued to outperform the younger children.

The significance in difference in scores between the two age groups was done for the two lists separately, for easy and hard words using the Mann-Whitney's U test. For both the lists, the scores obtained by the two age groups differed significantly for the easy ($Z = 2.83$, $p < 0.01$ for list-1; $Z = 1.80$, $p < 0.01$ for list-2) and hard words ($Z = 2.50$, $p < 0.01$ for list-1; $Z = 2.48$, $p < 0.01$ for list-2).

The finding of the present study regarding the performance of the two age groups indicates that there is a developmental trend with reference to the performance on easy and hard lexical words. As the age increases, the performance increases.

It has been noted by Elliott and Katz (1980) that though younger individuals may be familiar with a particular set of vocabulary though they would have had less exposure to the words when compared to older individuals. This reduced exposure to words adversely affects their perception of the same. A similar phenomenon could have occurred in the present study. Though the material selected for the present study were familiar to children as young as 5 to 6, it is highly likely that the younger group in the present study would have had less exposure to the words than the older children. This could have resulted in the frequency of occurrence of the word being lesser for the younger group of children and more for the older group. Thus, the poorer scores in the younger group can be attributed to their lower exposure to the words.

*Table 4. Mean scores and standard deviation (SD) for younger and older children on easy and hard words for list-1 and list-2 separately*

| Age groups | | List-1 | | List-2 | |
|---|---|---|---|---|---|
| | | Easy | Hard | Easy | Hard |
| Younger (6-6;11 yrs) | Mean* | 17.5 | 14.66 | 17.5 | 14.8 |
| | SD | 0.54 | 1.03 | 0.98 | 0.69 |
| Older (7-8 yrs) | Mean* | 18.8 | 16.22 | 18.7 | 16.1 |
| | SD | 0.78 | 0.83 | 1.17 | 0.83 |

*Maximum score = 20

**Performance of children with hearing impairment:** The mean scores and the standard deviation for the easy and hard words for the 5 participants with hearing impairment while wearing their prescribed hearing aids are provided in Table 5. As these participants were evaluated with both lists, the scores of both lists are provided. As was seen in the normal hearing group, the children with hearing impairment performed better on the easy words when compared to the hard words. This was seen for the scores obtained in list-1 and list-2. The better performance of the children on the easy words when compared to the hard words was reflected in the scores obtained by each child (Figure 2). This shows that the group trend is reflected in the individual performance also.

The Mann Whitney U test revealed that there was a significant difference between easy and hard words for list 1 ($Z = 2.06$, $p < 0.05$) and list 2 ($Z = 2.04$, $p < 0.05$) in children with hearing impairment. In addition, the Mann Whitney U test was performed to check whether there was a significant difference between the scores obtained by the hearing aid users across the two lists. The results suggested, there was no significant difference between the two lists both for both easy as well as hard words ($Z = 0.38$, $p > 0.05$) and ($Z = 0.32$, $p > 0.05$) respectively. This indicated that the both lists were equally capable of detecting the perceptual difficulties faced by hearing aids users.

Thus, it is evident that the general trend that is seen in normal hearing children is also seen in children with hearing impairment. Such findings have also been reported by Kevin et al. (2008), who evaluated the performance of children using implants and/or hearing aid, with a Cantonese lexical neighbourhood test. They too observed that the children using implants and/or hearing aids performed better on the easy words and poorer on the hard words.

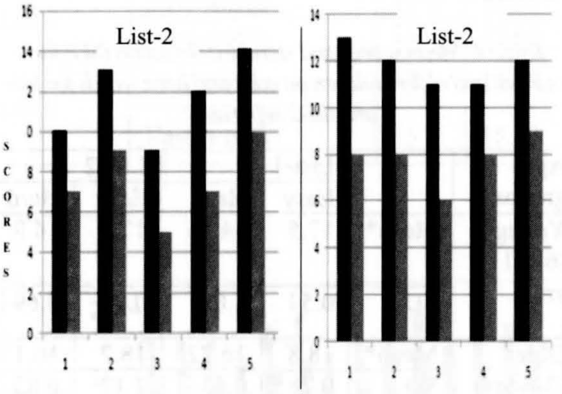


*Figure 2. Individual scores for lexically easy words and lexically hard words obtained by children with hearing impairment for list-1 and list-2.*

*Table 5. Mean word identification scores and standard deviation (SD) for individuals with hearing impairment*

| List | Word type | Mean* | SD | Range | |
|---|---|---|---|---|---|
| | | | | Min | Max |
| List 1 | Easy words | 11.60 | 2.07 | 9.00 | 14.00 |
| | Hard words | 7.60 | 1.94 | 5.00 | 10.00 |
| List 2 | Easy words | 11.80 | 0.83 | 11.00 | 13.00 |
| | Hard words | 7.80 | 1.09 | 6.00 | 9.00 |

*Maximum score = 20

*Table 6. Mean scores standard deviation (SD) of normal hearing children and children with hearing impairment for easy and hard words*

| Age groups | | List-1 | | List-2 | |
|---|---|---|---|---|---|
| | | Easy | Hard | Easy | Hard |
| Normal hearing (N = 15) | Mean | 18.33 | 15.60 | 18.20 | 15.53 |
| | SD | 0.98 | 0.99 | 1.18 | 1.20 |
| Hearing impaired ( N = 5) | Mean | 11.60 | 7.60 | 11.80 | 7.80 |
| | SD | 2.07 | 1.94 | 0.83 | 0.93 |

**Comparison of performance of children with normal hearing and children with hearing loss:** An observation of the mean scores obtained by normal hearing individuals and those using hearing aids highlighted that the scores obtained by those with normal hearing were far better than that got by the hearing aid users (Table 6). Further, the difference in scores between the two groups was less for the easy words (6.73 & 6.40 for list-1 & list-2 respectively) and more for the hard words (8.00 & 7.73 for list-1 & list-2 respectively).

The significance of difference between the performance between the normal hearing and the children with hearing impairment were compared using Mann Whitney's U test. For both the lists there was a highly significant difference between performances between the two groups. This was observed for both easy and hard word ($Z = 3.363$, $p < 0.05$) and ($Z = 3.325$, $p < 0.05$) respectively for list-1. Similarly for list-2 there existed a significant difference between the groups for the easy ($Z = 3.33$, $p < 0.05$) and hard words ($Z = 3.34$, $p < 0.05$).

The finding of the present study is in consonance that of Kirk et al. (1997). They too noted that on the LNT, significant effects were observed for lexical difficulty on word recognition of children using hearing prosthesis. Children with amplification devices performed poorer than normal listening children for both lexically easy and hard words.

In the present study, the hearing aid users were matched with the normal hearing children in counterparts. This reveals that the listening device worn by them was not able to compensate totally for their hearing deficit.

From the finding of the current study it can be inferred that the developed test is sensitive in identifying the perceptual difficulties in children using listening devices. The test can be useful to detect the specific lexical difficulties faced by children wearing hearing aids or any other listening devices.

## Conclusions

From the findings of the study it was observed 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 (low density and higher frequency of occurrence) were better perceived than lexical hard words (high density and lesser frequency of occurrence). Further, both lists yielded similar results, confirming that they were equal. This was noted in both groups of participants. Age had a significant effect on the performance of the children on both lexically easy and lexical hard words. As the age increased from 6 - 6;11 years to 7 - 8 years, the performance increased. The performed of the normal hearing participants was significantly better than that of the hearing aid users, though the two groups were matched in terms of language age.

Like any other speech identification tests, the developed test would help determine the perceptual deficits in children with hearing impairment, as well as in the selection of appropriate amplification device. As the Lexical neighbourhood test would provide information about the fine acoustic-phonetic errors in children using cochlear implants or hearing aids, it would provide information about the outcomes consequent to listening training.

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## APPENDIX

**List-1**- Teach, zoo, pond, fish, bus, one, week, bird, twin, voice, grapes, shoe, leg, Rich, stand, live, ant, thief, much, lion, nail, mat, ink, dot, pin, map, tip, bee, ring, sail, cave, feed, west, jar, sell, hat, bear, Tank, hit, skip

**List-2**- Time, spoon, speed, full, dog, wife, talk, bush, tree, egg, door, wash, lunch, rose, saw, love, toy, true, moon, cock, note, tray, snake, hide, pot, meal, top, post, rock, low, kite, van, whip, race, sit, hut, beat, sand, hear, ship.

**Lexically Easy Words – List-1**: Teach, zoo, pond, fish, bus, one, week, bird, twin, voice, grapes, shoe, leg, Rich, stand, live, ant, thief, much, lion

**Lexically Hard Words**- List-1: Nail, mat, ink, dot, pin, map, tip, bee, ring, sail, cave, feed, west, jar, sell, hat, bear, Tank, hit, skip

**Lexically Easy words- List-2**: Time, spoon, speed, full, dog, wife, talk, bush, tree, egg, door, wash, lunch, rose, saw, love, toy, true, moon, cock.

**Lexically Hard words- List-2**: Note, tray, snake, hide, pot, meal, top, post, rock, low, kite, van, whip, race, sit, hut, beat, sand, hear, ship.