Research Article

# Effect of Lexical Neighbourhood on Word Recognition Test: A Study in Turkish

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## Highlights

- Lexical density is a crucial point in word recognition test scores
- Word Recognition Scores should include words from spoken language
- Words that have many minimal pairs can manipulate word recognition test scores

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## ABSTRACT

**Background and Aim:** Word Recognition Test (WRT) is a widely used component of routine audiology battery. Several studies were conducted on the effect of words in word recognition lists and whether word difficulty level had an effect in word recalling process of patients. This study aims to compare the scores of patients to the designed Başkent WRT and commonly used Hacettepe WRT by focusing on the lexical neighbourhood.

**Methods:** Study carried out in an Ear Nose and Throat Department of a private university hospital between June and August 2021. 34 persons with sensorineural hearing loss and 34 persons without hearing loss was participated in the study. Designed WRT and widely used common WRT were presented to the participants.

**Results:** Results showed that common WRT included words with more lexical neighbours and sensorineural hearing loss group scores were significantly lower compared to designed WRT.

**Conclusion:** Persons with sensorineural hearing loss have a tendency to misunderstand presented words in WRT as they may trigger other words and misguide the patient.

**Keywords:** Speech audiometry; speech discrimination tests; hearing tests; psychoacoustics

## Introduction

Assessment of hearing through the speech is an important part of audiological tests as comprehension of the speaking is a very critical function of human auditory system [1]. The special test designed fort his assessment called as speech audiometry.

Word Recognition Test/Score (WRT/S) is a crucial part of speech audiometry battery. Clinicians use the test to observe impact of hearing loss in the real world communication skills of the patient, define the sufficient amplification by hearing aids and differentiate the cochlear and retrocochlear pathologies mainly [2-4].

For decades, hundreds of researchers tried to form WRTs with different approaches. However general view to design a WRT is to utilize monosyylabic and phonetically balanced words in the test, since Egan defined some criterias about the designing of WRT. Most researchers tried to adopt similar criterias for their own languages [5].

However word selection criterias were widely discussed and argued in the literature. Lehiste and Peterson claimed that the acoustic characteristics of a phoneme are modified by other phonemes surrounding it [6]. Their claim is that there is no way to construct a phonetically balanced monosyllabic WRT in classical understanding. According to another study, although it is possible to estimate the frequency of occurrence of sounds in "average" speech, the actual distribution of sounds in speech depends on the topic being discussed and who is speaking.

Lexical neighbourhood density may have an affect in spoken language recognition and distract the listeners attention [7]. For listeners discrimination of words that have more lexical neighbors is more difficult, differing by one phoneme insertion, deletion, or substitution, are more difficult to recognize than words with few lexical neighbors [7]. One phoneme insertion, omission and substitution in same word morphology may change the meaning and this phonemenon is called as minimal pair [7]. Phonological neighborhood plays an important role in most modern tests. According to this concept, words that can be separated from the target word by only one phoneme change are called phonological neighbors of that word.

According to Lexical neighbourhood density model of Luce and Pisoni organization of words depends on their similarity of occurance and the similarity of density (acoustic-phonetic cues) [8]. When a word is too dense, it means many other words may be triggered or recalled in audiotory tasks [9].

Phonological neighborhood plays an important role in most modern tests. According to this concept, words that can be separated from the target word by only one phoneme change are called phonological neighbours of that word. Meyer and Pisoni drew attention to this fact during their creation of the WRT and suggested that this may cause a difference in patient responses in cases such as rescoring the test or education level [10]. In Turkish monosyllabic words, there are wide phonological neighborhood relations with both vowel and consonant phonemic changes. As Turkish has a rich phonemic inventory, minimal pairs are oftenly occur in this language.

In Turkey, designated WRTs have a distribution of following structures;

Consonant+Vowel

Vowel+Consonant

Consonant+vowel+consonant

Consonant+vowel+consonant+consonant

Due to this situation, confusion of the patient may be observed during WRT. The goal of this study was to compare the lexical neighbourhood relations of Hacettepe WRT and Başkent WRT and compare the WRT scores of both tests in persons with sensorineural hearing loss.

## Methods

Designing a phonetically balanced list was not the goal of this study. Thus the position of phonemes in words and their distribution in the lists were ignored.

Word samples for lists were obtained from both written and verbal sources. For the frequency of the words, the Turkish Language Association's written Turkish Language Frequency dictionary [11] was used and the most frequently used words were selected for each allaphone. Phonemic inventory of Turkish (including allaphones and semi vowels) were selected from the "Dictionary of Colloquial Language and Turkish Speech" by Ergenç 1995 and 2002 [12, 13] and "Speaking and Diction/ Speaking Human" by Gürzap [14]. Detailed process can be seen in Figure 1.

To form a raw word datapool, selection of first ten words for every phonemes were targeted. If the total number was below 10, medial position in the word was included. As a small number of monosyllabic words that has vowels in the initial position in Turkish, priority for word selection was given to vowels.

As an indication of power analysis, for the raw word data were collected

Some phonemes that has the feature of semi vowel like /ğ/, /v/, /y/ and allophones of vowels like /a/, /i/ which are articulated in a longer period of time as a function of duration are not observed in monosyllabic words in Turkish. Lists included monosyllabic words for most of the phonemes, but phonemes mentioned above are used in Turkish language only with words more than two syllables. Thus most frequent bisyllabic words that includes /ğ/, /v/ and /y/ as semi vowel and /a/ and /i/ as longer allaphones were chosen for the lists.

Then, since the main basis of the study is the use of verbal language, a program with the theme of news, art, economy, sports, documentary and television series was selected from the Turkish Radio and Television Corporation (TRT) television channel, where standard language examples can be seen more often, and the related program was transcribed.Theme programs (for 2019) were News: TRT main newsletter, Series: Champion, Documentary: Explorers of Civilization, Art: Life Art, Economy: Economy 24/7, and Sports: TRT sports bulletin.

The words obtained from the written and oral media are collected in a pool and for allophones (/ğ/, /v/, /y/, /a/, /r/, /n/) that can only be observed in multisyllabic words; two-syllable words were chosen. Monosyllabic words were chosen for allophones that do not require multisyllabic word structure.

A statistical study was conducted to evaluate the selected words and it was determined that the sample size required for the familiarity evaluation should have consisted of 384 people between the ages of 18–50. The words obtained from oral and written media were presented to 384 people with different socio-cultural backgrounds (from literate to graduate). Distribution of participants were 72 persons (35 females, 37 males) as literate, 71 persons (41 females, 30 males) as primary school, 72 persons (38 females, 34 males) as secondary school, 73 persons (38 females, 35 males) as high school, 64 persons (34 females, 30 males) as graduate, and 32 persons (14 females, 18 males) as postgraduate.

Surveys were formed for the word famliarity and they were presented to participants via face to face interviews or online survey forms. Each word has been used with a carrier sentence in the survey. Participants were asked to evaluate the recognition of the words by scoring between 1 and 4. According to the results obtained, words with 4 points were selected by eliminating very well known (4 points) and never known (1 point), not well known (1 point). Studies show that frequently used words in a language are recognized more easily than less frequently used ones [15, 16]. Words that had 2 (known) and 3 (well known) points were included in the lists to avoid of the manipulation of familiarity.

## Participants

In the study, 34 patients with congenital sensorineural hearing loss between the ages of 18 and 40 were included as the study group, and 34 age- and gender-matched healthy hearing participants were included as the control group. The study was carried out in the clinic of Ear Nose and Throat Diseases Department a private university hospital between June 2021 and August 2021.

Inclusion criteria for the study group were: being between the ages of 18–40; presence of hearing loss of 25 dB and above as the lower limit according to pure tone audiometry; hearing threshold of 10 dB below the noise level as upper limit according to pure tone audiometry; lack of conductive and mixed type hearing loss; and lack of any neurological and psychiatric disorders. Inclusion criteria for control group were: being between the ages of 18–40; normal ear nose and throat finding in both ears; andlack of a history of upper respiratory tract infection that may have an obstructive effect on the external ear canal during the study.

Participants with the neurological and psychiatric disorders and the finding of perforation in the eardrum or external auditory canal in otoscopic examination were excluded from the study.

## Presentation of lists

The pure tone hearing thresholds of the individuals included in the study were obtained between 125–8000 Hz by the Interacoustics AC 40 (Assens, Denmark) audiometer device. According to the results obtained after the audiometric evaluation, the hearing thresholds were determined by taking the pure tone averages (PTA) at 500–4000 Hz. In order to objectively evaluate the presence of middle ear functions and acoustic reflexes of the participants, immitansmetry test was performed with the

GSI TympStar V1 tympanometer (Grason-Stadler, Eden Prairie, MN, USA). After the application of the standard audiological battery (otoscopic examination, pure tone averages, immitansmetry test) to the participants, the above-threshold speech scores were evaluated without hearing aid via TDH–39 supraaural headphones.

After the participants' thresholds were determined with pure tone averages test, speech reception thresholds were evaluated and WRT lists were presented to the participants without a specific order. In other words, the first presented WRT wasn't chosen as Başkent WRT nor Hacettepe WRT intentionally. After the first WRT presentation, the participants rested for 20 minutes for not being familiar with words and then the other WRT was introduced.

Tos um up the presentation, if the Başkent WRT was presented as first, then the Hacettepe list were presented as second to the same participant after the rest. Presentation of both lists were done via a USB and a recorded male voice.

### Randomized matching of the word lists

The resulting word inventory of 200 words was randomly distributed to the lists so that each phoneme was represented in the lists at least once.

The Başkent Word Lists (BWL) were divided into A, B, C, D lists consisting of 50 words each. Again, each list was randomly matched with the Hacettepe Word Lists (HWL). Accordingly, the comparison lists are as follows:

BWL A – HWL 2

BWL B – HWL 4

BWL C – HWL 1

BWL D – HWL 2

### Statistical method

Data were analyzed with IBM SPSS V23. All analyzes were performed at 95% confidence interval. Conformity to normal distribution was evaluated with the Shapiro Wilk test. Independent two-sample t-test was used to compare normally distributed data according to paired group. Paired two-sample t-test was used to compare the normally distributed data between two dependent groups within the group. Chi-square test was used to compare categorical variables according to groups. Categorical data as deviation and median (minimum–maximum) were presented as frequency (percentage). Significance level was taken as $p<0.050$.

## Results

### Descriptive analysis of participants

Participants of both control group and study group were matched based on age and gender. There was no statistically significant difference between the distributions of gender according to the groups ($p=0.808$). There was no statistically significant difference between the mean age values of the groups ($p=0.236$). In Table 1 statistics of population are given.

A statistically significant difference was found between the right PTA mean values between two groups ($p<0.001$), as expected. While the mean of the hearing impaired group was 45.0 dB HL, the mean of the control group was 7.0 dB HL. A statistically significant difference was found between the left mean PTA values of the groups ($p<0.001$). While the average of the hearing impaired group was 46.1 dB HL, the average of the control group was 6.0 dB HL. There was no difference between the right and left mean PTA values in the hearing impaired and control groups ($p>0.050$). Detailed data was given in Table 2.

Lexical neighborhood relationships in the subtests were examined with the two sample paired t test. Looking at the data, more lexical adjacency relations are observed in Hacettepe Word Recognition Test (HWRT) than Başkent Word Recognition Test (BWRT) , which is statistically significant for all positions in the word except for word medial. The relationship between the Başkent lists and the Hacettepe lists is statistically significant compared to the lexical neighborhood relations at the word initial, ($p=0.003$) and word final ($p=0.002$). The comparision of lexical neighbourhood in word medial position in both lists did not have a significant differance, ($p=0.039$). Detailed data may be seen in Table 3.

The mean scores of two groups were compared for right ear. While the mean of the hearing impaired group was 83.3 for Hacettepe WRT, the mean of the control group 97.5 and it was significantly higher, ($p<0.001$). For Başkent WRT statistically significant difference was found between the mean scores, 87.2 for sensorineural hearing loss (SNHL) and 98.2 for control ($p<0.001$).

When the responses of the hearing impaired group to both tests were compared in the sum of the subtests, a

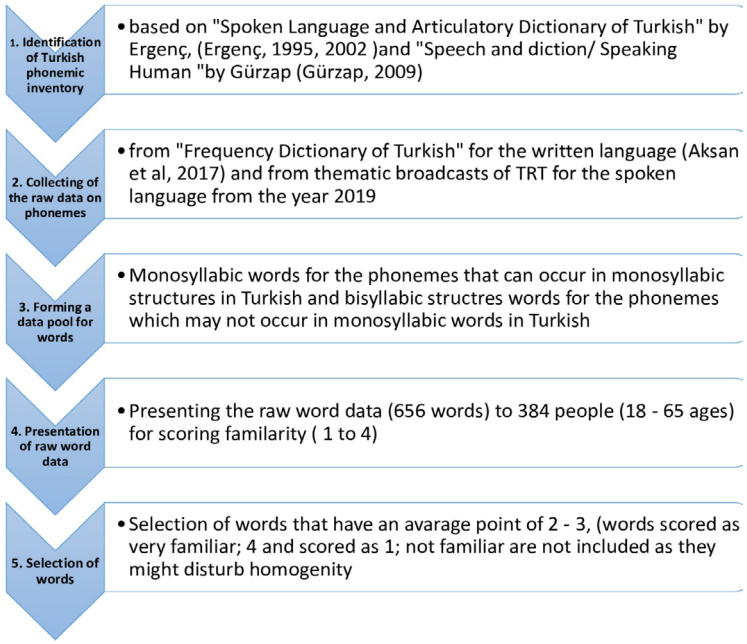


**Figure 1.** Stages of word selection criteria

statistically significant difference was found between the right ear scores of Hacettepe and Başkent WRTs (p<0.001). While the Hacettepe WRT average was 84.1, the Başkent WRT average was 87.2. There was no significance for the control group, as it was 97 for Hacettepe WRT and 100 for Başkent WRT, (p=0.221). Detailed data was given in Table 4.

The scores of two groups were compared for left ear. While the mean of the hearing impaired group was 83.3 for Hacettepe WRT, the average of the control group 97.7 and it was significantly higher, (p=0). For BWRT statistically significant difference was found between the scores, 87.2 for SNHL and 98.2 for control (p<0.001). When the responses of the hearing impaired group to both tests were compared in the sum of the subtests, a statistically significant difference was found between the left ear scores of commonly used and designed WRTs (p<0.001). While the HWRT average was 83.3, the BWRT average was 87.2. There was no significance for the control group, as it was 98 for HWRT and 100 for BWRT, (p=0.152). Detailed data was given in Table 5.

## Discussion

Findings of this study revealed that participants had a tendency to confuse words more when the number of minimal pairs or possible accessible words increased due to the increase in lexical neighbourhood density. Results showed there was a statistically significant difference between the four subtests designed and the answers given by the patients to the Hacettepe word recognition list.

Speech perception and comprehension may be described as the travel of acoustic cues into abstract units or representations that allow us to access the word mean-

**Table 1.** Comparison of gender and age by groups

| Gender | Sensorineural hearing loss group | | Control group | | Test statistic | p |
|---|---|---|---|---|---|---|
| | Number of participants | Percentage | Number of participants | Percentage | | |
| Male | 16 | 47.1% | 17 | 50% | $\chi2$=0.059 | 0.808 |
| Female | 18 | 52.9% | 17 | 50% | | |
| Age | Mean±SD | Mean(min-max) | Mean±SD | Mean(min-max) | t=1.198 | 0.235 |
| | 31.5±7.3 | 33.5(18.0-40.0) | 29.4±7.5 | 30.0(18.0-40.0) | | |

$\chi^2$; Chi-square test statistic, t; two independent samples t-test statistic

**Table 2.** Pure tone average of right and left ears in both groups

| Pure tone average | Sensorineural hearing loss | | Control | | Test statistic | |
|---|---|---|---|---|---|---|
| | Mean±SD | Mean(min.-max) | Mean±SD | Mean(min-max) | | |
| PTA Right | 45.0±18.4 | 40.0(24.0-90.0) | 7.0±5.5 | 7.5(0.0-20.0) | t=11.524 | <0.001 |
| PTA Left | 46.1±19.5 | 40.5(24.0-90.0) | 6.0±4.3 | 5.0(0.0-15.0) | t=11.724 | <0.001 |
| Test statistic | t=–1.032 | | t=1.473 | | | |
| p | 0.309 | | 0.150 | | | |

PTA; pure tone average

ing [17]. The majority of studies in the field revealed that words with high density were recognized less accurately and slowly [18-21].

When a speaker produces words, the listener tried to activate best possible matches due to acoustic information, [22]. A perfect word recognition appears when the acoustic information of the speaker and correct lexical input are matched in the listener's mental lexicon. Temporal and spatial acoustic cues for discriminating phonemes and words generally does not function in people with hearing loss. This leads patients not to conceive phonemic alterations properly. Same situation was also observed in people without hearing loss [23-25].

Studies also showed that language should be interpreted as a part of whole cognitive system, not as seperately, [26, 27]. Visual, motor, sensorial and memory skills of cognitive system works together with the language system, so individual differences also have an impact on the language related tasks among adults [28].

All phonemes in a language inventory have different acoustic features as a function of frequency and intensity. According to Nissen et al, phonemes have an acoustic structure that frequently changes in use in a particular linguistic context in natural speech [29]. For this reason, it is almost impossible to determine the phoneme distribution in a 50-word list in a way that can simulate the spoken language, especially if the lists are created with a verbal corpus. Considering that our study included the

Table 3. Comparision of lexical neighbourhood in both lists

| List | Total number for word initial | Mean lexical neighbourhood | Total number for word middle | Mean lexical neighbourhood | Total number for word final | Mean lexical neighbourhood |
|---|---|---|---|---|---|---|
| Başkent list A | 171 | 3.42 | 73 | 1.46 | 140 | 2.8 |
| Hacettepe list 2 | 271 | 5.42 | 90 | 1.8 | 267 | 5.34 |
| r | 1.58 | | 1.23 | | 1.9 | |
| Başkent list B | 142 | 2.84 | 72 | 1.44 | 138 | 2.76 |
| Hacettepe list 4 | 254 | 5.08 | 76 | 1.52 | 274 | 5.48 |
| r | 1.78 | | 1.05 | | 1.98 | |
| Başkent list C | 176 | 3.52 | 72 | 1.44 | 161 | 3.22 |
| Hacettepe list 1 | 232 | 4.64 | 85 | 1.7 | 285 | 5.7 |
| r | 1.31 | | 1.18 | | 1.77 | |
| Başkent list D | 215 | 4.3 | 77 | 1.54 | 193 | 3.86 |
| Hacettepe list 3 | 228 | 4.56 | 78 | 1.56 | 241 | 4.82 |
| r | 1.06 | | 1.01 | | 1.24 | |

**Table 4.** Comparison of word recognition test scores between and within groups for right ear

| | SNHL | | Control | | Test statistic* | p |
|---|---|---|---|---|---|---|
| | Mean±SD | Mean (min-max) | Mean±SD | Mean(min-max) | | |
| Right HWRT | 84.1±8.8 | 84.0(62.0-96.0) | 97.5±2.2 | 97.0(94.0-100.0) | t=–8.696 | <0.001 |
| Right BWRT | 87.2±8.1 | 89.0(70.0-100.0) | 98.2±2.7 | 100.0(92.0-100.0) | t=–7.464 | <0.001 |
| Test statistic** | t=–5.664 | | t=–1.248 | | | |
| p | <0.001 | | 0.221 | | | |

SNHL; sensorineural hearing loss, HWRT; Hacettepe word recognition test, BWRT; Başkent word recognition test

*t; independent two samples t test, **t; paired two sample t-test statistic

phonemic inventory but did not consider the phonetic balance, it can be said that the phonetic balance did not have a significant effect on the answers given to the lists for this study.

Clinicians believed that using words including fewer phonemes (speech sounds) have an advantage to spread out less acoustical cues on lexical information, [30]. Using monosyllabic structures may lead to another problem for the listener: confusion on phonemic discrimination and word discrimination. As the distribution and frequency of syllabic structures may differentiate in different language systems, strict word selecting criterias may cause problems. In addition, no clear evidence has been found that using monosyllabic words are more advantegous to evaluate the hearing function [31]. Martin et al. compared the Northern University WRT list and their monosyllabic list containing nonsense syllable material with 15 patients with SNHL. The results of the study showed that there was no significant difference in distinguishing words and nonsense monosyllabic words in SNHL patients [32]. Similar results were obtained when comparing several word lists such as the Central Institute for the Deaf (CID) W-22 and NU-6 speech materials [33].

Limitations of the study

This study was carried out with adults between the ages of 18–40 to avoid from the risk of presbycusis and possible lack of concentration in the pediatric group. To be able to generalize the results, new studies should be performed with SNHL group, firstly, and the other types of hearing loss also can be included. As a secondary limitation, study may be repeated with same design with the phonetically balanced words in order to compare the actual results of phonetic balance on SNHL.

## Conclusion

Mean density values for both word initial and word final positions mean that the number of possible accessible words in the commonly used word lists are approximately twice as high at the word initial and word final positions compared to the designed word list. As a clinical practice it may also be interpretated that the possibility for a patient to misunderstand and access to

**Table 5.** Comparison of word recognition test scores between and within groups for left ear

| | SNHL | | Control | | Test statistic* | p |
|---|---|---|---|---|---|---|
| | Mean±SD | Mean(min-max) | Mean±SD | Mean(min-max) | | |
| Left HWRT | 83.3±9.8 | 84.0(58.0-96.0) | 97.7±2.2 | 98.0(94.0-100.0) | t=–8.398 | <0.001 |
| Left BWRT | 87.2±7.8 | 90.0(70.0-100.0) | 98.2±2.9 | 100.0(90.0-100.0) | t=–7,733 | <0.001 |
| Test statistic** | t=–5.724 | | t=–1.465 | | | |
| p | <0.001 | | 0.152 | | | |

SNHL; sensorineural hearing loss, HWRT; Hacettepe word recognition test, BWRT; Başkent word recognition test

*t; independent two samples t test, **t; paired two sample t-test statistic

another word in the lexicon is significantly stronger in the presentation of Hacettepe word recognition test. During the routine practice of word recognition test, patients just hear and repeat the word presented. A visual cue or optional visual responses with a closed ended options are not used during WRT implementation. So when the number of minimal pairs increase, risk of recalling other words are also more possible. Different approaches may allow us to review our knowledge on routine audiological batteries.

## Ethical Considerations

### Compliance with ethical guidelines

Information on informed consent was signed by all participants. The study was conducted with the Declaration of Helsinki. Permission was obtained from Ethics Committee for the Research (project No: 20/33).

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### Authors' contributions

BA: Study design, acquisition of data, interpretation of the results, statistical analysis, and drafting the manuscript; LNO: Study design, revision the manuscript, supervision of the study.

### Conflict of interest

There is no conflict of interest.

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