

RESEARCH ARTICLE

Psychometric function characteristics of Persian consonant-vowel-consonant words

Mohammad Ebrahim Mahdavi*^{ORCID}, Atefeh Rabiei^{ORCID}

Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Received: 2 Dec 2020, Revised: 27 Dec 2020, Accepted: 27 Dec 2020, Published: 15 Jan 2021

Abstract

Background and Aim: Evaluation of word recognition score requires multiple lists that must be similar in terms of difficulty level. There is currently no such word lists for the Persian language. The aim of this study was to construct several lists of Persian monosyllabic words with psychometric homogeneity.

Methods: The most common monosyllabic words were collected from a book of Persian word frequency. The selected monosyllabic Consonant-Vowel-Consonant (CVC) words were presented randomly to 30 normal hearing participants with the age range of 18 to 25 years. The presentation level was from 0 to 40 dB in 8 dB increments. The characteristics of psychometric function were determined for all words using the logistic regression.

Results: The Persian CVC monosyllabic words have different difficulty levels with threshold varying from 2.8 to 37.2 dB HL and the slope from 2.3 to 16.4 %/dB.

Conclusion: The final result of the present study is three full lists of monosyllabic words with CVC syllabic structure that have the same mean threshold and slope of psychometric function. The 25-word half-lists of each full list are similar in terms of psychometric characteristics.

Keywords: Psychometric function; Persian monosyllabic words; speech audiometry

Citation: Mahdavi ME, Rabiei A. Psychometric function characteristics of Persian consonant-vowel-consonant words. *Aud Vestib Res.* 2021;30(1):50-5.

Introduction

Performance of word recognition in the quiet is an integrated part of basic speech audiometry that have several clinical applications, including detection a retrocochlear lesion, selection and fitting of an amplification, monitoring a progressive hearing loss and for compensation purposes.

The Persian is a branch of Indo-Iranian languages, which is a branch of Indo-European language. As a non-tonal language, there are several dialects in the Persian such as Tehrani, Isfahani, Shirazi, Kermani, but the standard dialect is the most common one that is used in official communications, and in educational and media environments.

The history of developing the Persian monosyllabic word lists for speech audiometry goes back to Mosleh [1]. This researcher collected all monosyllabic words from the four-volume Moin's Persian dictionary [2]. Mosleh determined the relative frequency of Persian phonemes, and compiled 12 25-word lists. These 12 lists included five Consonant-Vowel-Consonant (CVC) lists, four Consonant-Vowel-Consonant-

* **Corresponding author:** Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Damavand Ave., Tehran, 1616913111, Iran. Tel: 009821-77542057, E-mail: mahdavime@sbumu.ac.ir

Consonant (CVCC) lists, and three combined CVCC and CVC lists that are claimed to have phonemic balance [1]. According to Delfi et al. [3], Mosleh's word lists contain unfamiliar words that are not commonly used in the Persian-speaking conversations and the word lists are not equivalent in terms of word familiarity [3].

The psychometric function relates the level of physical intensity of a stimulus to perceptual sensitivity. The psychometric function is usually described by two characteristics; threshold and slope. The intensity level corresponding to 50% correct recognition is defined as threshold (50%). The slope is the rate of change of correct recognition with the change of intensity level. For speech recognition, the function is S-shape, so that at the intensity levels lower than the threshold, the probability of word recognition towards 0%, and at the levels higher than the threshold, the probability tends to 100%. The slope of psychometric function represents the degree of homogeneity of the difficulty of speech materials [4]. Previous studies on speech audiometry have used various statistical methods to establish the psychometric function [5-7]. The most common statistical method in these studies is the logistic regression, in which a nonlinear relationship is established between the intensity level of stimulus presentation as a continuous variable and a binary variable (correct or incorrect recognition of spoken material) [8].

Although there are studies that have investigated the psychometric homogeneity of Persian 1–10 monosyllabic digits in quiet and noise [9,10], there is currently no list of monosyllabic words that have psychometric homogeneity for evaluation of word recognition performance in Iran. The present study aimed to develop Persian monosyllabic CVC word lists for speech recognition protocols.

Methods

Initially, all monosyllabic words were drawn from the Frequency Dictionary of Persian [11] that contains 5000 most frequently used words in the Persian language. There were 549 monosyllabic words in this book including 254 monosyllabic CVC words and 295 monosyllabic

CVCC words. The words with the following conditions were excluded; name of digit or color, conjunctions and prepositions, having an unusual and non-cultural meaning and proper name.

The remaining 197 CVC words were professionally recorded by a native Persian-speaking man at the studio in standard Persian dialect. To enhance the recording quality, each word was uttered three times by the speaker. Higher-quality recordings in articulation and intonation were selected. Each word was digitized as a 24-bit wav file at a sampling rate of 44.1 kHz. The mean root-mean-square of the words equated to the calibration tone of 1000 Hz.

The digitized words were randomly distributed in 23 to 25-word lists using a custom program. Each list had a code and printed to record the data. Given that there are seven presentation levels from 0 to 40 dB HL, it is required to make seven random sequences from the lists. The word lists were presented ascending from 0 dB to 40 dB HL in each of the 8 dB steps.

The characteristics of the psychometric function, including threshold (50%) and slope of the function at threshold point or slope (50%) for each word were determined using the logistic regression [8]. The words which psychometric function characteristics exceeded 1.2 SD of the mean recognition function of 197 CVC words were excluded. Finally, 150 words remained, which were randomly distributed in three lists of 50-word. The words in each full list were sorted by threshold and slope. Even row words were listed as the half-list A and odd row as the half-list B. The raw data was reanalyzed for obtaining the psychometric function characteristic of the half-lists.

Results

The threshold (50%) of common Persian words used in the current study ranged from 2.85 dB HL (word /sæf/) to 37.20 dB HL (word /qæd/). Slope (50%) varied from 2.27 %/dB (word /qæd/) to 16.41 %/dB (word /sæf/). Fig. 1 shows the psychometric function of all CVC words using the logistic regression model.

Threshold (50%) and slope (50%) of 150 words was within 1.2 SD of mean threshold (50%) and

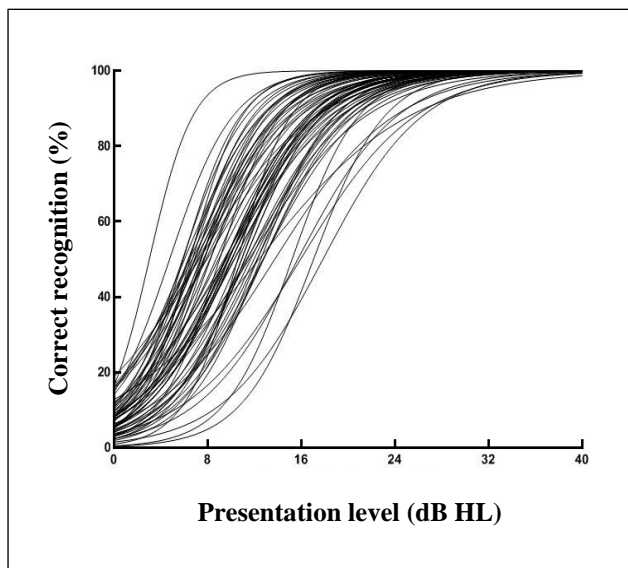


Fig. 1. Individual psychometric functions of 197 Persian consonant-vowel-consonant words (Logistic regression).

slope (50%) of all CVC words. These 150 words were sorted by difficulty level and distributed into three 50-word lists. We entitle these word

lists firstly constructed in Shahid Beheshti University of Medical Sciences as SBMU-1 words. Table 1 contains the mean and standard deviation of the percentage of correct recognition of the full and half-lists at the presentation levels along with characteristics of the functions. As this table shows, the recognition score tends to 0% at 0 dB HL and tends to 100% at 40 dB HL. Fig. 2 indicates the mean functions of 25-word half-list of each full list. The similarity of the psychometric functions of the half-lists makes it possible to use them interchangeably.

Discussion

The aim of this study was to compile several homogeneous lists of monosyllabic words that can be used in speech audiometry protocols. To achieve homogeneous lists, we chose words for each list based on the threshold and slope of the psychometric function. The result of this research was three lists of 50 CVC monosyllabic words that are very similar in terms of psychometric function characteristics. Because most audiologists use half-lists to determine word recognition score, two 25-word half-lists were compiled from

Table 1. Mean (standard deviation) of the psychometric function characteristics and the predicted corrected response (%) in the presentation levels for constructed word lists

	Mean (SD) of the psychometric function characteristics					Presentation level (dB HL)					
	Regression intercept	Regression slope	Threshold (dB HL)	Slope (50%) (%/dB)	Slope (20-80%) (%/dB)	0	8	16	24	32	40
List 1	2.57 (0.52)	-0.30 (0.05)	8.69 (2.01)	7.54 (1.23)	6.53 (1.07)	7.85 (3.54)	46.53 (14.09)	88.13 (7.77)	98.42 (1.42)	99.81 (0.22)	99.98 (0.03)
Half 1A	2.61 (0.51)	-0.31 (0.05)	8.62 (2.01)	7.75 (1.31)	6.71 (1.13)	7.55 (3.42)	47.23 (14.39)	88.83 (8.01)	98.56 (1.42)	99.83 (0.20)	99.98 (0.03)
Half 1B	2.53 (0.53)	-0.29 (0.05)	8.76 (2.04)	7.33 (1.14)	6.35 (0.99)	8.16 (3.70)	45.84 (14.05)	87.43 (7.62)	98.29 (1.44)	99.78 (0.23)	99.97 (0.04)
List 2	2.59 (0.69)	-0.31 (0.05)	8.52 (2.47)	7.77 (1.30)	6.72 (1.13)	8.23 (4.78)	47.65 (16.95)	88.53 (9.19)	98.43 (2.03)	99.79 (0.38)	99.97 (0.07)
Half 2A	2.65 (0.70)	-0.30 (0.06)	8.91 (2.40)	7.57 (1.40)	6.55 (1.21)	7.82 (4.42)	44.86 (15.94)	87.13 (9.53)	98.11 (2.41)	99.73 (0.49)	99.96 (0.09)
Half 2B	2.53 (0.68)	-0.32 (0.05)	8.13 (2.54)	7.96 (1.20)	6.89 (1.04)	8.65 (5.18)	50.45 (17.77)	89.93 (8.81)	98.75 (1.54)	99.86 (0.22)	99.98 (0.03)
List 3	2.57 (0.60)	-0.30 (0.06)	8.74 (2.22)	7.56 (1.44)	6.54 (1.24)	8.05 (4.07)	46.16 (15.74)	87.57 (8.24)	98.28 (1.58)	99.78 (0.26)	99.97 (0.04)
Half 3A	2.48 (0.52)	-0.30 (0.05)	8.58 (2.21)	7.42 (1.26)	6.42 (1.09)	8.50 (3.83)	47.41 (15.34)	87.87 (8.42)	98.23 (1.82)	99.76 (0.31)	99.97 (0.05)
Half 3B	2.67 (0.67)	-0.31 (0.06)	8.89 (2.26)	7.69 (1.61)	6.66 (1.39)	7.59 (4.33)	44.91 (16.34)	87.27 (8.22)	98.32 (1.35)	99.80 (0.19)	99.97 (0.03)

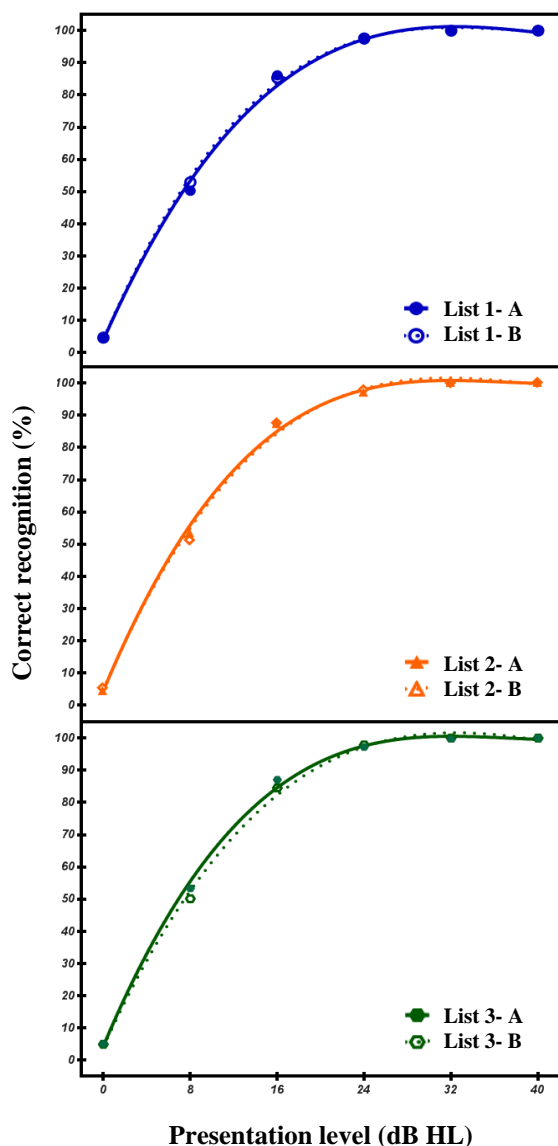


Fig. 2. The psychometric function of mean correct recognition for the half-lists (Third-degree polynomial).

each list, which are very similar to their full 50-word list in the characteristics of the psychometric function (Table 1, Fig 2).

The results of the present study confirm the fact that CVC monosyllabic words have different psychometric characteristics. This finding encourages the Iranian audiologist to employ the monosyllabic word lists with homogenous difficulty.

There are several studies that have developed word lists for different languages (Table 2).

As Table 2 shows, the threshold (50%) and slope values of the psychometric functions for monosyllabic words are in the range of 10.7-13.5 dB HL and 4.1-6.2 %/dB respectively. The results of the present study are in part comparable to the studies mentioned in this table. In out-of-date American-English studies on the monosyllabic words Nu-6 and W-22, the slope of the psychometric function was in the range of 3.6-5.6 %/dB [12,13]. Even in one language, the slope of the psychometric functions of developed word lists may not be the same. Wilson and Oyler [13] compared the psychometric functions of the W-22 and the NU-6 words recorded by the same carrier phrase and speaker. Threshold (50%) was 15.6 dB HL for W-22 and 13.4 dB HL for NU-6 words. The words Nu-6 had a slightly steeper slope than the words W-22. Heckendorf et al. [7] reported the slope of 4.1%/dB for W-22 and 1.9 %/dB for PAL-50 words [14]. The observed differences in the characteristics of the psychometric function among previous studies are due to various factors such as the sex of the speaker, intensity steps in word presentation, and calibration of spoken material [14]. Statistical models used, and the syllable type (CVC versus CVCC) of monosyllabic words are different across the studies.

This study, like several other studies [15-17], has not considered the phonemic balance of word lists because First, researchers believe that a 50-word list does not achieve the relative phonemic frequency of a language [17,18]. Second, according to Martin et al. [19], the phonemic balance does not guarantee the audibility homogeneity. Third, the phonemic balanced words like Nu-6 in quiet cannot estimate the extent of speech communication problems in a noisy environments unless the recognition performance in quiet is weak [20].

Further studies are required to investigate the equivalency of the lists constructed in this study in presence of hearing loss.

Conclusion

The present study determined the psychometric characteristics of common and familiar Persian consonant-vowel-consonant words with standard

Table 2. The psychometric function characteristics of the monosyllabic words reported for several languages/dialects

Study	Year	Language/dialect	Threshold (50%) (dB HL)	Slope (50%) (%/dB)	Slope (20-80%) (%/dB)
Richard et al. [17]	2003	Korean (male voice)	11.4	5.0	4.4
		Korean (female voice)	10.7	5.1	4.4
Harris et al. [16]	2007	Russian (male voice)	11.5	5.8	5.0
		Russian (female voice)	11.6	5.6	4.9
Tsai KS et al. [5]	2009	Mandarin	11.1	4.5	4.1
Durankaya et al. [21]	2014	Turkish	13.5	6.2	5.4
Current Study	2020	Persian	8.7	7.6	6.6

dialect, and constructed three full 50-words lists entitled Shahid Beheshti University of Medical Sciences-1 (SBMU-1) word lists that have psychometric homogeneity. Each full list has two 25-word half-lists with very similar psychometric characteristics.

Acknowledgments

This article has been extracted from A. Rabiei MSc. thesis on Audiology submitted to Shahid Beheshti University of Medical Sciences with Ethical Code No. IR.SBMU.RETECH.REC.1398.716.

Conflict of interest

The authors state that there was no conflict of interest.

References

- Mosleh M. [Development and evaluation of a speech recognition test for Persian speaking adults]. *Audiol.* 2001;9(1-2):72-6. Persian.
- Moin M. *An intermediate Persian dictionary*: Tehran: Amir Kabir Publishing Corporation; 1992.
- Delphi M, Jarollahi F, Tahaie SA, Modarresi Y, Kamali M. [Evaluating Mosleh monosyllabic word lists in adults with noise-induced hearing loss]. *Audiol.* 2013;22(3):14-22. Persian.
- Wilson RH, Margolis RH. Measurements of auditory thresholds for speech stimuli. In: Konkle DF, Rintelmann WF, editors. *Principles of speech audiometry*. Baltimore: University Park Press; 1983. p. 79-126.
- Tsai KS, Tseng LH, Wu CJ, Young ST. Development of a mandarin monosyllable recognition test. *Ear Hear.* 2009;30(1):90-9. doi: 10.1097/AUD.0b013e31818f28a6

- Harris RW, Kim E, Eggett DL. Psychometrically equivalent Korean bisyllabic words spoken by male and female talker. *Commun Sci Disord.* 2003;8(1): 244-70.
- Heckendorf AL, Wiley TL, Wilson RH. Performance norms for the VA compact disc versions of CID W-22 (Hirsh) and PB-50 (Rush Hughes) word lists. *J Am Acad Audiol.* 1997;8(3):163-72.
- MacPherson A, Akeroyd, MA. Variations in the slope of the psychometric functions for speech intelligibility: A systematic survey. *Trends Hear.* 2014;18(6): 1-26. doi: 10.1177/2331216514537722
- Ebrahimi A, Mahdavi ME, Jalilvand H. Auditory recognition of Persian digits in presence of speech-spectrum noise and multi-talker babble: a validation study. *Aud Vestib Res.* 2020;29(1):39-47. doi: 10.18502/avr.v29i1.2368
- Heidari M, Mahdavi ME, Heidari F, Akbarzadeh Baghban A. Auditory recognition of Persian digits in multi-talker babble noise: a preliminary study. *Aud Vestib Res.* 2015;24(3):25-31.
- Miller C, Aghajanian-Stewart K. *A Frequency Dictionary of Persian: Core vocabulary for learners*. 1st ed. New York, NY: Routledge; 2018.
- Beattie RC, Edgerton BJ, Svihovec DV. A comparison of the Auditec of St. Louis cassette recordings of NU-6 and CID W-22 on a normal-hearing population. *J Speech Hear Disord.* 1977;42(1):60-4. doi: 10.1044/jshd.4201.60
- WilsonRH, Oyler AL. Psychometric functions for the CID W-22 and NU Auditory Test No. 6. Materials spoken by the same speaker. *Ear Hear.* 1997;18(5):430-3. doi: 10.1097/00003446-199710000-00008
- Wilson RH, Carter AS. Relation between slopes of word recognition psychometric functions and homogeneity of the stimulus materials. *J Am Acad Audiol.* 2001;12(1):7-14.
- Harris RW, Nissen SL, Pola MG, McPherson DL, Tavartkiladze GA, Eggett DL. Psychometrically equivalent Russian speech audiometry materials by male and female talkers. *Int J Audiol.* 2007;46(1):47-66. doi: 10.1080/14992020601058117
- Harris RW, Kim E, Eggett DL. Psychometrically

- equivalent Korean monosyllabic speech discrimination materials spoken by male and female talkers. *Korean Journal of Communication Disorders*. 2003;8(1):217-43.
17. Nissen SL, Harris RW, Channell RW, Conklin B, Kim M, Wong L. The development of psychometrically equivalent Cantonese speech audiometry materials. *Int J Audiol*. 2011;50(3):191-201. doi: [10.3109/14992027.2010.542491](https://doi.org/10.3109/14992027.2010.542491)
 18. Wong LL, Soli SD. Development of the Cantonese hearing in noise test (CHINT). *Ear Hear*. 2005;26(3):276-89. doi: [10.1097/00003446-200506000-00004](https://doi.org/10.1097/00003446-200506000-00004)
 19. Martin FN, Champlin CA, Perez DD. The question of phonetic balance in word recognition testing. *J Am Acad Audiol*. 2000;11(9):489-93; quiz 522.
 20. Wilson RH, McArdle R. Speech signals used to evaluate functional status of the auditory system. *J Rehabil Res Dev*. 2005;42(4 Suppl 2):79-94. doi: [10.1682/jrrd.2005.06.0096](https://doi.org/10.1682/jrrd.2005.06.0096)
 21. Durankaya SM, Şerbetçioğlu B, Dalkılıç G, Gürkan S, Kırkım G. Development of a Turkish monosyllabic word recognition test for adults. *J Int Adv Otol*. 2014; 10(2):172-80. doi: [10.5152/iao.2014.118](https://doi.org/10.5152/iao.2014.118)