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RESEARCH ARTICLE

Auditory recognition of Persian digits in multi-talker babble noise: a preliminary study

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Abstract

Background and Aim: Digits are suitable materials for hearing assessment of wide range of patients including children and adults with various language abilities. Single monosyllabic 1-10 digits in triplet formant have been used for measuring speech recognition threshold in signal-to-noise ratio. The purpose of this study was to determine signal-to-noise ratio (SNR) needed for 50 percent correct recognition of Persian monosyllabic digits (1-10) in multi-talker babble noise.

Methods: Thirty unique triplet set of nine 1-10 monosyllabic Persian digits were created and mixed with multi-talker babble noise. Signal-to-noise ratio varied from -18 to +3 dB in 3-dB steps. Digits were presented binaurally to 17 normal hearing young adults aged 18-25 years. Speech recognition threshold in SNR (SRTsnr) was measured by Spearman-Karber equation and probit regression method.

Results: Mean SRTsnr of Persian digits, had minimum value of -12.7 dB for digit 3 and maximum value of -6.8 dB for digit 9. Mean (standard deviation) of SRTsnr was -9.5 (2.1) dB. There was no statistical significant difference between mean SRTsnr of the males and the females for all digits (p>0.05).

Conclusion: Persian 1-10 monosyllabic digits are not homogeneous in terms of SNR needed for reaching 50% correct recognition. Mean SRTsnr of Persian digits is comparable to German and Polish digits but is higher than English digits.

Keywords: Word recognition in noise; digits; normal hearing; Persian

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Introduction

Evaluation of speech recognition in noise has been conducted with test materials such as monosyllabic words and sentences, and several tests have been designed for this purpose including quick speech in noise (QSIN), hearing in noise test (HINT) with sentences as test material, and word-in-noise (WIN). These tests determine signal to noise ratio (SNR) required for 50% correct recognition of words, sentences or keywords in a sentence [1-4] that in this article is referred to as speech recognition threshold in signal-to-noise ratio (SRTsnr), or speech recognition threshold in terms of signal to noise ratio. Although sentences are considered to represent normal conversation conditions well and possess high level of face validity, use of sentences as test materials in noise has limited clinical application, since listener needs to understand the whole sentence in optimal signal to noise ratio (SNR) condition. Meanwhile, understanding the whole sentence may not be possible for some patients due to hearing loss or poor language skills. On the other hand, it is not possible to simply use sentence recognition in noise test in children and many users of cochlear implant devices [5]. Although above limitations are less applicable to monosyllabic words, test materials such as digits can be considered as special types of words, which have none of the usual limitations of sentence and monosyllabic words [5-7].

Pursuant to Smits et al., recognition of monosyllabic digits (1-10) in noise was used for two purposes; screening for loss of hearing through telephone or internet, and evaluation of speech recognition in noise [5,8]. In these studies, digits were presented mostly as triplet, like 2-8-5. Compared to single digits, digit triplets have several advantages: First, they have a sharp psychometric function that makes estimate of SRTsnr with low standard deviation possible. Second, given that there are only three digits, which are substantially lower than the normal working memory capacity (7±2), it is not difficult to memorize them. Third, it has been demonstrated that, independently of recognition capability, digit triplets can accurately measure SRTsnr. Moreover, since digit triplets are context-free, especially when presented in random order, the effect of learning by memorizing is minimized. Thus, a digit triplet can be presented several times to testee, without learning affects his SRTsnr [5,9,10]. Study of recognition of digit triplets has been conducted in various languages such as Danish by Smits, Canadian English by Rudmin, English by Wilson et al., and Polish by Ozimek et al. [9,11-13]. Given several languages and dialects in Iran, it is imperative to have auditory processing tests, in which test materials contain little language influence, such as digits. The present study aims to measure SRTsnr of Persian monosyllabic digits (1-10) in the presence of multi-talker babble noise in young people with normal peripheral hearing for the first time in Iran.

Methods

Using randomization program, 30 unique sets of triple digits were made from 1-10 (excluding the two-syllable digit 4) with no digit repeating in each set, and with overall 10 repeats for each digit. Persian digits, uttered by an adult native speaker of Persian, were recorded in a studio and saved as a data file. For making multi-talker babble noise, voices of six Persian speakers (3 men and 3 women), after removal of silent gaps and normalization of sound waves, were electronically mixed so that speeches of none of the speakers were apprehensible. Using calibration tone of 1000 Hz, output of laptop (Pro book 4520s model, China) connected to phone (Philips SHM 6500/10, China) was calibrated for the noise of 75dB SPL intensity. The SNR was adjusted from -18 to +9 in 3dB steps. Inter-digit gap in each item was set for 500 ms, and inter-item gap for 5 seconds. A short tone of 480 ms was placed 650 ms before each item, to warn the testee against oncoming test item.

This descriptive cross-sectional analytical study was conducted on 17 people (7 men and 10 women) between 18 and 25 years of age, with the mean age of 21.3(SD= 2.9), and normal peripheral hearing (hearing threshold of 20 dB or better in audiometric frequencies, with monosyllabic word recognition score of 90% or higher) in a quiet room under headphone. Items were presented in ascending order from SNR of -18 to +9. Initial assessment showed recognition of 100% at SNR of +3 dB, thus items with SNR +6 to +9 were not performed. Number of each correctly recognized digit at each level of SNR was calculated. SRTsnr for each digit and overall digits mean were determined using probit regression and Spearman-Karber equation in dB with Statgraphics Centurion XVI software. Fig. 1 shows the manner to determine SRTsnr in probit regression method. Slope of 20% to 80% of psychometric function revealed by probit regression was calculated according to Wilson and Carter [14]. Raw data were

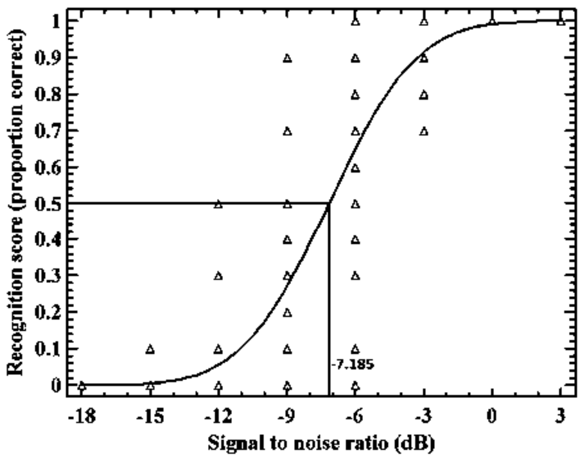

Fig. 1. SRTsnr estimation using probit regression showing -7.185 dB for digit 2

converted into rationalized arcsine units (rau) as described by Studebaker [15] for statistical analysis. Repeated measure ANOVA was used to compare mean SRTsnr of different digits, and Mann-Whitney U test to assess gender effect on correct recognition score in the presence of noise at different SRNs.

Results

Mean and standard deviation of total digits recognition score at different SNRs in percentage of correctly recognized for different sexes are shown in Fig. 2. Accordingly, gender had no effect on mean recognition at different SNRs ($p>0.05$ at all SRNs). Comparing correct recognition at each SNR for each digit showed no significant difference between two sexes ($p>0.05$ at all SNRs for all digits). Fig. 3 compares psychometric functions of separate digits and psychometric function of mean recognition of all digits.

Table 1 presents SRTsnr and slope of 20% to 80% section of psychometric function. According to Table 1 and Spearman-Karber

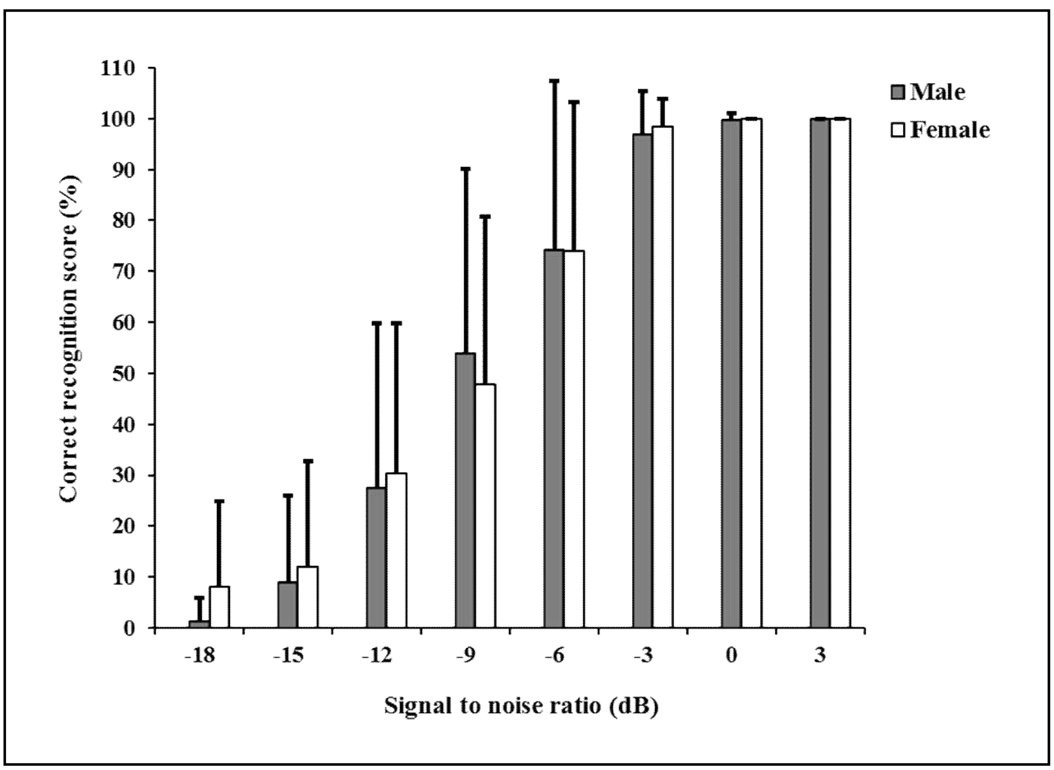

Fig. 2. Mean (standard deviation) correct recognition score in different SNRs for studied males and females.

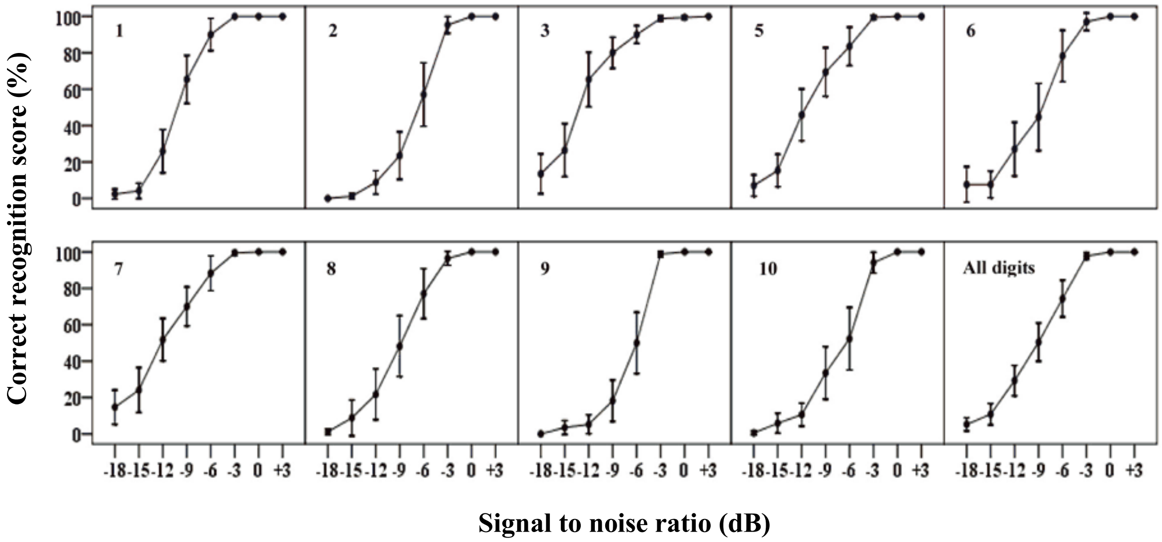

Fig. 3. Mean (standard deviation) of correct recognition of different digits as a function of SNR

equation, SRTsnr varies from -6.8 dB for digit 9 to -12.7 dB for digit 3. In terms of mean SRTsnr of recognition of different digits, no significant difference was found between digits 1, 6 and 8, and digits 2, 9 and 10. However, mean SRTsnr of other digits was significantly different from each other ($p<0.05$). The interaction between gender and different digits SRTsnr was not significant ($p=0.323$). According to Fig. 4, pattern of SRTsnr of different digits is similar in men and women. As shown in Table 1, apart from small difference in standard deviation, probit regression and Spearman-Karber equation show similar mean SRTsnr of single

Table 1. Mean (standard deviation) SRTsnr (dB) of the Persian digits using Spearman-Karber equation and probit regression and slope of 20-80 percent region on psychometric function

	Mean (SD)		
Digit	Probit regression	Spearman-Karber	Slope (20-80%) (%/dB)
1	-10.1 (0.8)	-10.1 (2)	11.5
2	-7.2 (1.3)	-7.1 (2.2)	11.7
3	-12.7 (1.7)	-12.7 (2.6)	8.2
5	-11.1 (1.4)	-11.1 (2.6)	8.6
6	-9.5 (2.4)	-9.4 (3.2)	8.4
7	-12 (1.6)	-11.9 (2.4)	7.8
8	-9.2 (0.8)	-9.1 (2.7)	9.4
9	-6.9 (3.3)	-6.8 (1.9)	12.0
10	-7.5 (0.8)	-7.4 (2.6)	9.5
All digits	-9.6 (0.3)	-9.5 (2.1)	8.2

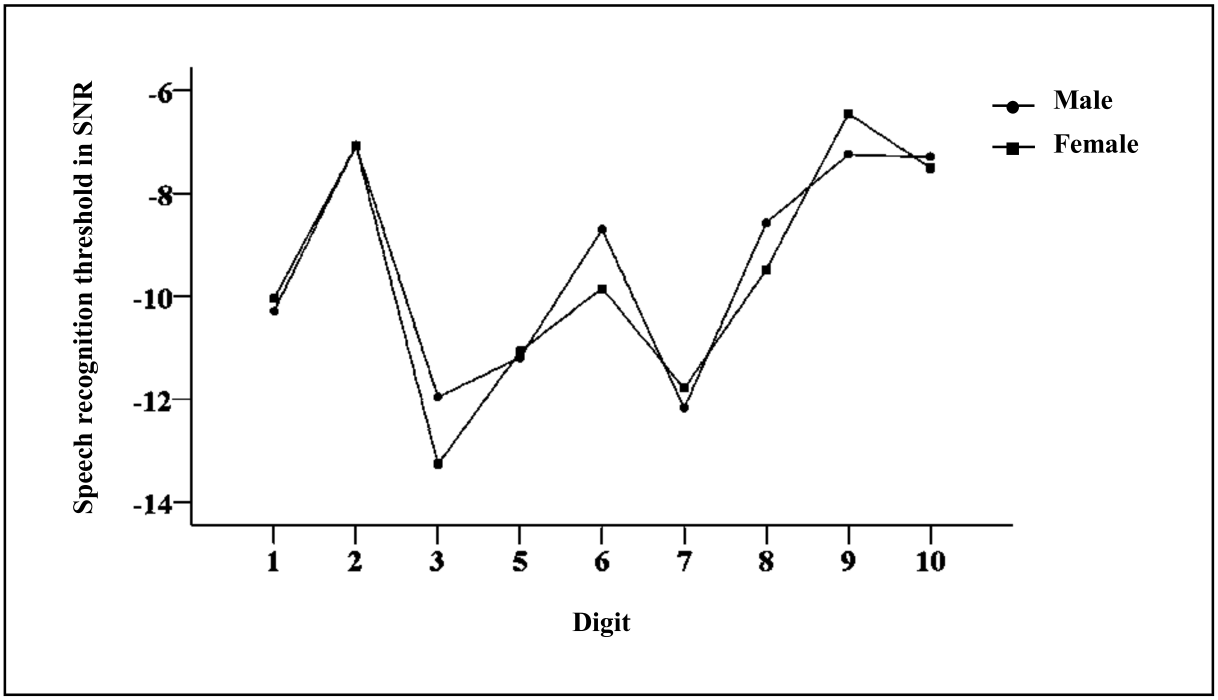

Fig. 4. Mean SRTsnr of the Persian digits for studied males and females using Spearman-Karber equation.

and all digits.

Discussion

This study aimed to assess SRTsnr of recognition of Persian digits in noise in order to develop a test of recognition of Persian digits in noise. This preliminary study showed a significant difference in size and distribution between recognition of Persian digits in noise and the English version by Wilson and Weakley [7]. which was also performed binaurally in multi-talker babble noise. In their study, mean SRTsnr of recognition of English digits was -15 dB with a standard deviation of 4.1, but in the Persian version, mean SRTsnr was -9.5 dB with a standard deviation of 2.1. There was also a significant difference between the two studies in SRTsnr range, in that the lowest SRTsnr was found for digit 3 (-12.7 dB) and the highest was found for digit 9 (-6.8 dB) with a difference of 5.62 dB in the present study, while in the English version, a difference of 12.6 dB was found between the highest SRTsnr for digit 2 (-17.6 dB) and the lowest for digit 5 (-6 dB) The difference may be attributed to the difference in digit and noise spectrum between Persian and English languages. However, mean SRTsnr of all digits in Persian (-9.6 dB) is highly similar to that in Polish (-9.4 dB), and German (-9.3 dB) as cited in a study by Ozimek et al., but it is higher than mean SRTsnr for English digits (-14.7 dB) [7,13].

Mean correct recognition of digits at different SNRs and mean SRTsnr of digits were independent of gender effect, which eliminates the need for adult gender-specific normalization. This preliminary study showed 100% recognition of Persian digits by young adults at SNR from 0 dB to 3 dB, and no higher SNRs are required. At SNR equivalent to -18 dB, Persian digit recognition approaches zero. These values are necessary for construction of the Persian test of digits in noise. No significant difference was found between probit regression and Spearman-Karber in mean SRTsnr for different digits. Even though in probit regression method, overall results are used to estimate SRTsnr for different digits, Spearman-Karber equation provides separate SRTsnr for different digits for each person. That is why SRTsnr has lower standard deviation in probit regression method compared to Spearman-Karber equation.

Slope of psychometric function becomes more important when using digit recognition in noise to screen hearing through the phone or internet compared to auditory processing goals [9,13]. According to Table 1 and Fig. 3, psychometric function slope at 20% to 80% range is in close proximity for digits 1, 2, and 9. Other digits are also comparable in terms of slope.

Digits recognition in noise is easier than recognition of single monosyllabic words or words within sentences. In Persian QSIN test developed by Tahaei, and used by Khalili et al., SNR for 50% recognition for key words of the test varied from -0.69 dB to -2.19 dB, which is significantly different from mean SRTsnr of -9.6 dB found in this study for Persian digits [16]. In Wilson and Weakley study, comparing SRTsnr of English digits recognition to NU.6 words, mean SRTsnr for overall digits was -14.7 dB and mean SRTsnr for words was +3.2 dB [7]. Part of the difference between digits SRTsnr and monosyllabic words SRTsnr is due to closed-set of digits and open-set of words in responding to test materials heard by the testee. In close-set tests, such as digits in noise, and consonants-vowels test or dichotic digits, guessing test materials is also an issue [17].

Since in Iran, there are no standard monosyllabic words such as Nu.6 acceptable by the scientific audiology community, and bilingual use of dominant language (Persian) makes assessment of speech recognition in noise problematic for bilinguals, digits recognition in noise (with no limitations of words or sentences) can better be used in hearing aid fittings and cochlear implantation in choosing and adjusting and evaluating the processing strategies. It is therefore recommended that a test for Persian digit recognition in noise be constructed and assessed for reliability.

Conclusion

Persian monosyllabic digits in multi-talker babble noise lack SRTsnr homogeneity. Digits 2, 9 and 10 have the highest SRTsnr, and digits 3, 5, and 7 have the lowest. Gender has no effect on correct recognition of monosyllabic digits (1-10) in multi-talker babble noise.

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