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Word-In-Noise Perception Test in Adults

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Abstract

Background: It is essential to have a test that creates the best competitive conditions for evaluating meaning perception. Therefore, this study aimed to investigate the psychometric properties of the Word-In-Noise Perception test (WINP) using Homotonic-Monosyllabic Words (HMWs) and Spectrum Speech Noise (SSN) for Persian speakers aged 18 to 22 years.

Method: This study was a test-development type that was conducted in a cross-sectional-comparative way. Assessments included 110 young Persian speakers. The evaluations included checking the state of general health, sleep and mental states, basic audiological evaluations, dichotic digit test and WINP. Mann-Whitney and Friedman tests were used to compare group scores.

Results: The validity and reliability of WINP using HMWs and SSN were determined. The mean Conversion Rate (CVR) and mean Content Validity Index (CVI) of the HMWs were 0.99 and 0.95, respectively. The minimum acceptable reliability (ICC) was also calculated for single and mean measurements. The results showed that the obtained scores are stable and without measurement errors. Normal values of WINP were obtained using HMWs and SSN. Gender was not an effective factor in causing differences in mean WINP scores. There was no significant difference between WINP mean scores in Signal-to-Noise Ratios (SNR) in different noises between the right and left ears. Also, there was a significant difference between mean scores of WINP in SNRs from -5 to +15 for left and right ears.

Conclusion: The psychometric properties of the WINP using HMWs and SNN have been confirmed for Persian speaking adults.

Keywords: Health status, Perception, Psychometrics, Reference values, Reproducibility of results, Signal-to-noise ratio, Speech

Introduction

Since everyday conversations and social communication are conducted in competitive situations, the most important human need for the sense of hearing is speech-in-noise perception (1). Word-In-Noise Perception test (WINP) using Homotonic-Monosyllabic Words (HMWs) along with the use white noise was recently developed (2-5). WINP consists of 6 lists, each list containing 25 HMWs, whose structural pattern is consonant/vowel/consonant and the vowel of each list is the same. Since there are 6 vowels in Persian, there are 6 HMW lists in this test (Appendix 1). However, considering that the signal strength of white noise is evenly distributed over time, white noise cannot be a suitable masker for the speech signal (2). For this reason, the use of Speech Spectrum Noise (SSN) prevents the excessive masking of the speech signal and increase the accuracy of the WINP (2,4).

Speech processing is carried out with the participation

Appendix 1. Lists of Phonetically balanced monosyllabic words of Iranian Persian language with the arrangement of homotonic-monosyllabic words for word-in-noise perception test, based on the Iranian Persian international transliteration alphabet *

n	Vowel / e /	Vowel / o /	Vowel / i: /	Vowel / ɒ: /	Vowel / æ /	Vowel / u: /
1	Σen	Σol	Si:b	Kɒ:r	Sær	gu:ʃ
2	Sen	Pol	Σi:b	Bɒ:r	Dær	Mu:ʃ
3	Dʒen	gol	Dʒi:b	Mɒ:r	Kær	Du:ʃ
4	gel	Kol	Si:r	Qɒ:r	Σær	Nu:ʃ
5	Del	Khol	Pi:r	Zɒ:r	Pær	Hu:ʃ
6	Hel	Qom	Di:r	Jɒ:r	Sær	Dʒu:ʃ
7	Sel	gom	Σi:r	Hɒ:r	Xær	Tʃu:b
8	Vel	Xom	Qi:r	Dɒ:r	Nær	Mu:r
9	Ʒel	Dom	Zi:r	Nɒ:r	Tær	Σu:r
10	Beh	Som	Dʒi:r	Sɒ:r	gær	Su:r
11	Meh	Σok	Mi:r	Xɒ:l	Sæm	Du:r
12	Deh	Nok	Ti:r	Sɒ:l	Næm	Zu:r
13	Leh	Σod	Mi:ʃ	Mɒ:l	Xæm	Ku:r
14	Deq	Xod	Ni:ʃ	Bɒ:l	Gæm	Dʒu:r
15	Neq	Por	Pi:ʃ	Zɒ:l	Dæm	Nu:r
16	Nej	Sor	Ki:ʃ	Kɒ:l	Bæm	Bu:r
17	Dej	Σor	Bi:ʃ	Σɒ:l	Kæm	Tu:r
18	Keʃ	Lor	Fi:l	Tʃɒ:l	Qæm	Du:d
19	Σeʃ	Lop	Mi:l	Nɒ:m	Jæx	Su:d
20	Fer	Boz	Bi:l	Σɒ:m	Σæb	Ru:d
21	Qer	Hoz	Si:x	Dɒ:m	Tæb	Ku:d
22	Kez	Moz	Mi:x	Dʒɒ:m	Læb	Bu:d
23	Vez	Motʃ	Ni:m	Kɒ:m	Σæk	Zu:d
24	Mes	Xoʃ	Bi:m	Vɒ:m	Tæk	Bu:q
25	Hes	Σoʃ	Si:m	Rɒ:m	Sæg	Du:q

* Emami SF. The use of homotonic monosyllabic words in the Persian language for the word-in-noise perception test. Aud Vestib Res. 2024. 33(1):28–33. doi.org/10.18502/avr.v33i1.14271.

of the auditory brain and the brainstem. The brainstem is sensitive to the fundamental frequency of sound (f0), which is the psychoacoustical equivalent of speech vowels, and can be observed in the frequency following response. This is why musicians who are exposed to more f0 are better at understanding speech in noise than normal people.

In general, the brainstem is most sensitive in detecting musical rhythm and speech pitch, which is done based on the tonotopic map. The auditory brain also monitors and controls the neural signals received from the brainstem as a correction and coordination center, and its parts even participate in pitch processing based on the tonotopic map. There is another processing in the auditory brain called the phonemotopic mapping, which is not sensitive to f0 in this function.

In fact, the auditory brain is sensitive to the frequency difference between the first and second formant of vowels for processing the phonemes and detecting the consonants, and it is the f1-f2 connection processor that understands the meaning and concepts. As a result, a sentence uttered by different speakers (woman, man and child) conveys the same meaning to the listener (1-6). Accordingly, if HMWs are presented to the individual in order and sequence, they cause the brainstem to have the least participation in speech processing and the neural function to focus on recognizing speech consonants by the auditory brain (3-6). It seems that WINP using SSN and HMWs can be a valid measure in the fields of prevention, diagnosis and rehabilitation of hearing disorders. For this reason, this study aimed to investigate the psychometric properties of the WINP using HMWs and SSN for Persian speakers aged 18 to 22 years.

Materials and Methods

Setting

This was a cross-sectional, comparative, experimental study. The location of the sound recording was the acoustic recording studio of the Hamadan University of Medical Sciences, the Fourier analysis of HMWs and psychoacoustics measurement of the recorded audio file were performed and the practical work was carried out at the Department of Audiology of Hamadan University of Medical Sciences.

Inclusion criteria included high school level, age less than 22 years and more than 18 years. Normal conditions in general health, nocturnal sleep, hearing thresholds, middle ear function, acoustic reflexes, word-in-noise discrimination, dichotic digit and pitch pattern scores, and no history of the following: head injury, ototoxicity, metabolic and cardiovascular diseases, anemia, diabetes, hypothyroidism, hyperthyroidism, medication use psychedelic, nervous system diseases and addiction.

Exclusion criteria comprised unwillingness to continue participating in the research, inappropriate cooperation, and insufficient attention from participants.Participants included 110 Persian-speaking young people (61 males and 49 females) with a mean age of 20 (0.56) years. The ethical considerations of this research were met by maintaining privacy, respecting the safety of participants, and ensuring that the assessments were free of charge.

The main outcome variables were obtained after explaining the practical work steps and obtaining written consent to participate in the study, a 28-item general health questionnaire, the Petersburg Sleep Quality Index, and a brief psychological status examination among the participants (131 people). Those who had normal results in this stage (n=118) underwent audiological tests, which included acoustic immittance measurement (by clarinet middle ear immittance device), pure tone audiometry, speech reception threshold and word-in-noise discrimination (by Interacoustic AC33 audiometer), dichotic digit and pitch pattern tests (with the audio files recorded on a laptop). Of the 118 participants, 110 had normal results on the mindfulness-based assessments, which were considered our core sample size and were assessed by the WINP using HMWs and SSN.

In order to assess the content validity, HMWs lists were provided to 20 Persian linguists. After reviewing the responses, the levels of Content Validity Ratio (CVR) and Content Validity Index (CVI) were determined for each of the items related to specificity, simplicity and clarity for the word list. Words with CVR<0.7 and or CVR<0.42 were excluded. Psychoacoustics measurement of MMWs were performed using Fourier analysis. Then, in a studio equipped with the highest quality audio equipment, HMWs were recorded in silence with the voice of a female Persian speaker without accent.

HMWs with similar frequency bandwidth and energy level were selected and non-HMWs were eliminated. The generated SSN was speech-filtered white noise with a flat spectrum in the frequency range of 250 to 1000 *Hz* and an energy reduction of 6 *dB/octave* from 1000 to 6000 *Hz* (7). Finally, SSN was added to the recorded voice at Signal-to-Noise Ratios (SNRs) of -5, 0, +5, +10, and +15 *dB*.

The WINP practical task was conducted using HMWs and SSN at the participants' comfortable listening level (3). The recorded sound was presented to each ear separately through a high-quality headphone connected to the computer. Participants were asked to respond quickly, with a gap of 2000 *ms* between words. If there was no response, the next trial automatically began 2000 *ms* after the last word was played (4).

The interval between trials of each 25 HMW list was 1000 *ms*. In other words, there was a 1000 *ms* pause after the last word in each list was presented and then the first word from the second list was presented after 3000 *ms*. To calculate the WINP norm, the number of correct answers was multiplied by 4, resulting in a percentage score (4,5).

WINP reliability using HMWs and SSN was calculated in terms of repeatability across assessment times. Repeatability during testing was assessed using Intra-class Correlation Coefficient (ICC). WINP was assessed twice for participants, with a two-week interval between them, to avoid participants' memory loss, and all six lists of HMWs were presented to participants at each assessment. The median of all 6 lists in each ear was considered as the norm of that ear, and the median of the entire right and left ear was considered as the test norm. The values of the calculated indices in the two repetitions were completely identical and the correlation value was equal to one.

Data analysis

The analysis of the findings was performed using Stata17 software from StataCorp. Quantitative variables included median, Interquartile Range (IQR), mean, and standard deviation. Descriptive statistics were Kolmogorov-Smirnov and Shapiro-Wilk tests were used to examine the normality of data distribution. The Mann-Whitney and Friedman tests were used to compare the differences between scores. All statistical analyses were performed at a significance level of 0.05.

Results

In this study, the validity and reliability of WINP test using HMWs and SSN were determined in 110 Persian speakers. The mean CVR and mean CVI of the remaining words were equal to 0.99 and to 0.95, respectively. ICC was also calculated on individual and average measurements. An ICC close to 1 indicates greater validity of WPS and better consistency of HMWs across lists. The results showed that the obtained scores are stable and free from measurement errors. Normal WINP values were obtained using HMWs and SSN (Table 1).

The results of the Mann-Whitney test showed that there was no significant difference between the mean WINP at different SNRs between the right and left ears, given that the p-value of the test was greater than 0.05. Also, the results of Friedman's test showed that considering that the p-value of the test was less than 0.001 and there was a significant difference between the mean WINP for SNRs of -5 to +15 in the left and right ears (Table 2).

Since there were significant differences between SNRs, pairwise comparisons of SNRs were performed by Friedman's supplementary test (Table 3). Also, no significant difference was observed between the mean WINP scores by gender ($p=0.989$).

Discussion

By comparing the mean and standard deviation values of WINP using SSN for Persian speakers aged 18 to 22 years (at the SNRs of -5 dB=53±1.93, 0 dB=69±2.22, +5 dB=82±2.43, +10dB=90±1.50 and +15 dB=95±1.44) with the values obtained from the WINP using white noise for Persian speakers aged 18 to 22 years (at the SNRs of 0 dB=53±14.80, +5 dB=68.15±13.20, and +10 dB=88±12.60) in a recent study (4), it can be seen that the mean WINP using SSN is higher in both ears and the standard deviations are lower.

Previous researchers have reported that the high standard deviation of WINP using white noise in their studies (3-5) may be due to the occurrence of Central Auditory Processing Disorder (CAPD) in

Table 1. Reliability of the word-in-noise perception test (WINP) using homotonic monosyllabic words (HMWs) and speech spectrum noise (SSN) for Persian speakers aged 18 to 22 (n=110)

SNR	Intraclass correlation coefficient limit (0.95)		*ICC1	Intraclass correlation coefficient limit (0.95)		*ICC2	First test score				Second test score			
	Upper limit	Lower limit		Upper limit	Lower limit		IQR	M	Mean	SD	IQR	M	Mean	SD
-5	0.98	0.83	0.92	1.00	0.80	0.96	25.41	40	53	1.93	24.45	42	55	1.03
0	0.99	0.78	0.90	0.99	0.78	0.92	28.36	52	69	2.22	26.89	54	68	2.89
+5	0.98	0.79	0.95	0.98	0.79	0.93	23.18	66	82	2.43	22.68	64	83	3.74
+10	0.96	0.86	0.94	0.96	0.81	0.92	27.65	72	90	1.50	26.34	74	87	2.63
+15	1.00	0.88	0.96	1.00	0.85	0.95	26.47	99	95	1.44	24.96	97	95	1.08

SNR; signal-to-noise ratio, Interquartile range: IQR, Median or norm values: M, Standard deviation: SD, *ICC1: In mean of measurements, *ICC2: In one measurement.

Table 2. Comparing of mean scores of the word-in-noise perception test (WINP) using homotonic monosyllabic words (HMWs) and speech spectrum noise (SSN) for Persian speakers aged 18 to 22 years at different signal-to-noise ratio (SNR) by ear

Ear	SNR															** p
	-5			0			+5			+10			+15			
	M±SD	IQR	M	M±SD	IQR	M	M±SD	IQR	M	M±SD	IQR	M	M±SD	IQR	M	
Right	54±6.03	23.12	40	69±4.89	27.91	55	82±5.74	21.98	62	90±6.63	27.91	71	94±5.08	25.13	98	<0.001
Left	53±6.24	26.19	43	68±5.61	25.34	53	83±4.88	23.80	65	89±7.09	25.87	75	96±3.90	23.62	95	<0.001
* p	0.346			0.433			0.080			0.830			0.063			

*Mann-Whitney test, ** Friedman tests, SNR: signal-to-noise ratio.

Table 3. pairwise Comparing of mean scores of the word-in-noise perception test (WINP) using homotonic monosyllabic words (HMWs) and speech spectrum noise (SSN) for Persian speakers aged 18 to 22 years at different signal-to-noise ratio (SNR)

Right ear	SNR			
	-5-0	0-5	5-10	10-15
p-value	<0.001	<0.001	<0.001	<0.001
Left ear	-5-0	0-5	5-10	10-15
p-value	<0.001	<0.001	<0.001	<0.001

SNR: signal-to-noise ratio.

young adults (4), elderly (3) and patients with renal failure (5). In this study, it can be assumed that the lower limit of the mean WINP scores using SSN (in SNRs of -5 dB=48%, 0 dB=44%, +5 dB=64%, +10 dB=68% and +15 dB=84% probably occurs as a hidden impairment that cannot be detected.

Audiological tests used to diagnose CAPD are unable to localize lesions due to the simultaneous involvement of central auditory centers in various auditory processing functions (1,2,6). For example, word-in-noise discrimination, dichotic digit, and pitch pattern tests that can detect abnormalities of the auditory brain and brainstem (2). Various tests are usually used to diagnose CAPD, and since the WINP test minimizes the participation of the brainstem in vowel recognition, it can be one of the appropriate tests to assessment the function of the auditory brain in recognizing of speech consonants and lexical-semantic processing (3-5).

In silent conditions, the left hemisphere of the auditory brain prefers verbal stimuli (6,8). The left frontal pole, left dorsolateral prefrontal cortex, and right posterior parietal lobe are activated in any function related to attentional mechanisms, especially speech perception (9,10). In the presence of noise, each hemisphere works with the participation of all cortical areas (11,12). Two broad lexical-semantic processing streams have been described for speech-in-noise perception: Bilaterally and largely symmetric streams, organized in superior temporal gyrus. The dorsal stream or posterior part of the superior temporal gyrus is for sensory-motor interaction, which is left-dominant and involves structures at the parietal-temporal-frontal junction (13).

In the process of speech-in-noise perception, the intraparietal sulcus is activated and the planum temporale also acts as a computational center and plays an important role in distinguishing two simultaneous speech signals. The left insula cortex processes fundamentals frequency sounds containing semantic information, and the right insula cortex processes fundamentals frequency sounds containing phonological information. The ventral premotor cortex also enhances the ability to recognize vowels, especially when the signal-to-noise ratio is reduced. Mirror neurons in the medial frontal cortex, which are active in imitative functions, are also involved in speech-in-noise perception (2,14,15).

When SNR decreases, and speech-in-noise perception in becomes difficult, brain areas associated with semantic processing and speech production are recruited and techniques that improve listeners' understanding are employed, such as speaking louder (2,10). Wernicke's area's principal function is speech perception, but it also participates in production. The main role of Broca's area's is in speech production, but it also plays a role in perception (2,9). When someone reads a text aloud, word imagery is created in the occipital cortex. Each word is formed in a spatial format, that is different for each person. Then, visual signals generated from the occipital cortex are transmitted to the angular gyrus and on to Wernicke's area (16).

Regardless of whether CAPD and other auditory impairments are unilateral or bilateral, speech-in-noise perception impairments appear to be due to damages to the superior temporal lobe of the language-dominant hemisphere, suggesting that speech inputs are processed asymmetrically at early stages (2,8). Bilateral superior temporal lobe dysfunction causes word deafness, a condition in which pure tone hearing thresholds are within normal limits. But the ability to speech perception is virtually nil. Damage to posterior temporal lobe regions is the strongest predictive of speech perception deficits (in aphasia) (12).

Damage to the posterior portion of superior temporal gyrus (in certain forms of aphasia) causes speech perception deficits. However, these conditions involve only mild phonological impairments (13). Anterior temporal lobe regions have also been implicated in sentence-level lexical-semantic processing. Patients with semantic dementia show bilateral anterior temporal lobe atrophy along with deficits in lexical tasks such as naming, semantic association, and single-word comprehension (14). The anterior and inferior temporal lobes appear to be more involved in the process of meaning-making, while the anterior temporal lobe is involved in integrating specific forms of semantic knowledge across different dimensions (17).

Damage to posterior temporal lobes, particularly along the middle temporal gyrus has been associated with speech perception deficits (14). It is well-established that auditory inputs can have rapid and automatic effects on speech production. For example, delayed auditory feedback of one's own voice disrupts speech fluency. Adult-onset deafness is associated with decreased articulation, suggesting that auditory feedback is important in maintaining articulation inflection (15,17).

Damage to the left dorsal posterior superior temporal gyrus is associated with production disorders (12). In particular, such damage is associated with conduction aphasia, a syndrome usually caused by stroke and characterized by good speech perception, but frequent phonological errors in production, naming difficulties, and difficulty with word-for-word repetition (16).

Finally, since patients with CAPD and various types of peripheral hearing loss have difficulty speech-in-noise perception (2,10), it is essential to perform WINP using SSN.

Conclusion

Psychometric properties of the WINP have been confirmed using HMWs and SNN for Persian-speaking adults.

Ethics approval and consent to participate

The study was approved by the research ethics committee of Hamadan University of Medical Sciences (Code: IR. IR.UMSHA.REC.1402.018). Informed written consent to participate in the study was provided by all participants.

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Conflict of Interest

The authors declare that they have no conflicts of interests.

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