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Word-in-noise perception test in children

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Abstract

Background The word-in-noise discrimination test evaluates the phonological aspect of speech based on the detection of the vowels. While word-in-noise perception (WINP) test is one of the speech perception exams and evaluates the ability to understand the meaning of words by discovering the consonants.

Until now, all word-in-noise tests have assessed speech discrimination performance, and for the first time, the normal values of the WINP test for adults have been determined. Since the normal values of WINP scores in children have not been reported, our research aimed to determine the normal values of the WINP test in children aged 5 to 13 years.

In this cross-sectional study, 120 Persian speaking Iranain children with normal hearing thresholds were evaluated from the beginning to the end of spring 2023. We divided them into 4 age groups (A = 5–7 < years, B = 7–9 < years, C = 9–11 < years, D = 11–13 < years). The evaluations included general audiology tests and WINP tests using hom-tonic-monosyllabic words (HMWs) at a signal-to-noise ratio of 5 dB.

Results Significant difference was observed between the mean scores of the WINP test in age group A (54%) compared to age group B (66%), (*Pv* = 0.04). Also, the differences between the mean scores of age group A compared to age groups C (70%) and D (69%) were significant (*Pv* = 0.01, *Pv* = 0.03).

Conclusions This article presented the norm values of WINP test scores for Persian speaking Iranian children aged 5 to 13 years. The norm values of WINP test scores in the age group of 5–7 years were lower than in the age groups of 7–13 years. The biggest change in the performance of speech perception in noise was observed in the age range of 7–9 years.

Keywords Speech, Word, Perception, Noise, Children

Background

For non-tonal languages, there are two main mechanisms for speech processing: *Phonological* and *semantic* [1]. Phonological processing includes features of pitch, accent, and rhythm of speech. Semantic processing includes choosing the correct word for a specific concept, as well as recognizing the features and syntax of words in a sentence [1, 2]. Speech processing is carried out in steps: (1) detection, which consists of recognizing separate syllables of a two-syllable word, which is the same mechanism of hearing the sound and is performed by the speech reception threshold test. (2) Recognition or differentiating monosyllabic words from each other based on the discovery of their vowels, which is done by word-in-noise recognition or speech discrimination score tests and using the list of non-photonic-monosyllabic words (non-HMWs) that have different vowels. (3) Interpreting or learning the first words in the mother tongue and understanding their meaning. (4) Perception or understanding of the meaning and grammatical position of the learned words is done by the WINP test, and the test materials include HMWs, that have a fixed vowel in each list (Additional file 1: Appendix 1) [1–4].

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Perception and production of speech interact with each other and each is a substructure of the other [4]. In such a way that without understanding the meaning of a sentence, it is not possible to express that sentence, and without expressing a sentence, it is not possible to understand it [1, 2]. This cooperation improves language processing in the central nervous system. For example, young children pronounce voiced vowels and consonants and are unable to produce voiceless consonants. These incomplete words they produce are meaningful to them, although they may not be understandable to others [3, 4].

The cochlea of the inner ear reaches full maturity in the first months after birth. At birth, there is no ability to recognize the gender differences in speakers' voices, and this ability gradually develops with age [1]. Determining the difference between noise and the speaker's speech requires a decade of listening experience [4]. Since the maturation of the neural system of speech perception and its related areas continues until the age of 14, at younger ages, the ability to understand speech in noise is weaker than that of adults [4, 5]. The maturity of the ears is also different from each other, the right ear reaches full development and adult function sooner, while this situation is associated with a delay for the left ear [1, 4]. In addition, the cooperation of non-sensory and cognitive issues such as attention, memory, internal body sounds, and auditory programs are effective in creating differences between children and adults in the temporal processing of sounds [3, 5, 6]. Therefore, this study aimed to determine the normal values of the WINP test in children aged 5 to 13 years.

Methods

This research was a cross-sectional work. Its practical measure was done from the beginning to the end of spring 2023. The participants involve 120 children in four age groups (A = 5–7 < years, n = 24; B = 7–9 < years, n = 36; C = 9–11 < years, n = 41, D = 11–13 < years, n = 29). The inclusion criteria were monolingualism (Persian native Iranian children), normal hearing in the frequency range of 250 to 8000 Hz with thresholds better than or equivalent to 15 dB [6], no history of underlying disorders, no ear diseases, no history of cognitive and listening problems. The exclusion criteria contained reluctance to participate in research, suffering from ear and cognitive difficulties, learning complications, hearing and speech perception problems, and bilingualism.

The practical measure

At the beginning of the work, the study procedure was explained to all participants and their parents signed the consent forms. They were evaluated by general audiological assessments, which included otoscopic examination, acoustic immittance testing (by clarinet middle-ear analyzer), pure tone audiometry (using AC33 audiometer, Interacoustics, Denmark), and WINP test (with an audio file). The HMWs were selected for the WINP test, which has a consonant-vowel-consonant (CVC) format (Additional file 1: Appendix 1) [1, 2, 4]. Since there are 6 vowels in the Iranian Persian language, 6 lists of 25-HMWs were used. All HMWs were presented using an audio file recorded by a woman's voice through high-quality headphones. To calculate the norm criterion of the WINP test, we multiplied the number of HMWs that the subject repeated correctly by 4, and the normatic criteria were expressed as percentages (25 × 4 = 100%). WINP test total mean was calculated by rounding the values obtained for the right and left ears [1, 2, 4].

Statistical analysis

Statistical analysis was done by SPSS17 and the normal distribution of variables was confirmed by the Kolmogorov-Smirnov test. Normal values and norm criteria were determined by mean and standard deviation. Multiple comparisons of the variables were checked by the Mann-Whitney test and the significance level was less than 0.05.

Results

In age group A (5–7 < years)

The mean total age = 5.46 (1.49), mean age of girls = 5.35 (0.97), mean age of boys = 5.60 (0.84), mean WINP test for right ears = 54.95 (9.41), mean WINP test for left ears = 53.43 (12.09), the total mean (norm value) of WINP test = 54%.

In age group B (7–9 < years)

The mean age = 8.46 (6.98), the mean age of girls = 7.97 (0.52), the mean age of boys = 8.95 (1.27), the mean WINP test for right ears = 66.13 (0.76), mean WINP test for left ears = 65.48(0.69). The overall mean of the WINP test = 66%.

In age group C (9–11 <years)

The mean age = 9.91 (0.29), the mean age of girls = 10.14 (0.84), the mean age of boys = 9.97 (1.36), the mean WINP test for right ears = 70.27 (0.39), the mean WINP test for left ears = 69.69 (0.99). The overall mean of the WINP test = 70%.

In age group D (11–13 < years)

The mean age = 12.80 (1.08), the mean age of girls = 12.36 (0.69), mean age of boys = 11.95 (1.14), mean WINP test for right ears = 69.11 (0.60), mean WINP test for left ears = 68.73(0.58). The overall mean of the WINP test = 69%.

Significant difference was observed between the mean scores of the WINP test in age group A compared to age group B ($P = 0.04$). Also, the differences between the mean of age group A compared to age groups C ($P_C = 0.01$) and D were significant ($P_D = 0.03$). There was no significant difference between the mean WINP scores of girls compared to boys ($Pv = 0.39$). The mean WINP of the right ears was higher than that of the left ears (Table 1), but the differences were not significant ($Pv = 0.51$).

Discussion

Until now, only the WINP test norm values have been determined for adults [4], and in this research, we determined its norm values for Persian speaking Iranian children aged 5 to 13 years. The findings showed that the mean WINP test scores for children aged 5 to < 7 years were lower than those of children aged > 7 to 13 years, and their differences were significant. The values obtained for the mean of the right and left ears of adults (14 to 35 years old) based on the WINP test were 67.47 (17.059) and 66.67 (15.548) [4], which are very similar to the values obtained of this research:

In age group 7–9 < years: right ears = 66.13 (0.76), and left ears = 65.48(0.69).
In age group 9–11 < years: right ears = 70.27 (0.39), and left ears = 69.69 (0.99).
In age group 11–13 < years: right ears = 69.11 (0.60), and left ears = 68.73(0.58).

While the mean obtained for the right [54.95 (9.41)] and left [53.43 (12.09)] ears of children aged 5 to 9 years was lower. Also, the mean WINP test scores of the right ears were higher than the left ears, which could be due to the superiority of the left hemisphere for speech perception. Also, the left hemisphere receives the neural signals that cross from the right ear, and thus a relative improvement in processing the signals of the right ear compared to the left side is created [3, 6].

Table 1 Mean ± standard deviation (S.D) of word-in-noise perception test of research participants (right ears = 120, left ears = 120)

Age (year)	Ear	Mean (S.D) %	Max	Min
5–7<	Right	54.95 (9.41)	60	22
	Left	53.43 (12.09)	58	20
7–9<	Right	66.13 (0.76)	68	24
	Left	65.48(0.69)	68	26
9–11<	Right	70.27 (0.39)	72	26
	Left	69.69 (0.99)	70	24
11–13<	Right	69.11 (0.60)	82	32
	Left	68.73(0.58)	80	30

Other research in the field of speech recognition and speech perception using other speech tests has been done by different researchers, which are as follows. Corbin et al. reported that speech perception in continuous speech noise reaches the level of young adults' abilities until about 10 years of age, but the speech perception score in intermittent speech noise reaches maturity and growth by 13–14 years of age, almost all children over the age of 14 will become adults [7]. Calandruccio et al. reported that in children, speech perception performance in noise is better when the noise is continuous compared to intermittent speech noise, and the performance of 11- to 13-year-old children is similar to that of young adults. While in spoken conversations, their scores are 10% poorer than young adults [8].

Wightman et al. stated that compared to adults, children have more problems understanding speech in noise, which is caused by the immaturity of the nervous system and delayed development. A significant difference in the performance of children and adults causes a 36% decrease in recognizing words in noise for children aged 5–7 compared to adults aged 19–34 [9]. However, the materials used in each test can have very significant effects on the results of the work [1, 3, 7].

Darwin and his colleagues confirmed that speech perception performance in noise is related to a series of dominant and specific sound characteristics, which include the basic frequency of the human voice, the frequency of formants, the length of the vocal cords, the size and length of the speech organs [10]. Leibold and his colleagues reported that in 7–13-year-old children, the difference in the gender of speakers does not improve the speech perception score in noise, which is due to the immaturity of the neural system of speech perception. In other words, the recognition of the diversity of sounds based on gender is absent at birth and gradually develops during development [11].

Ren et al. investigated word perception performance in noise in 3- to 6-year-old children. Their findings showed that the features of the words in terms of the degree of familiarity and commonness in the language have an effect on the scores of understanding the word in noise, and in the words that were more difficult and unfamiliar, their scores are lower. Also, with increasing age, the percentage of the scores increases, and in the condition of silence, the scores of all children were better than they had in noise [12].

Liu et al. conducted a word recognition test in noise for children aged 4–7 years. Their findings showed that familiar and easier words produce better scores and the percentage of scores increases as children age [13].

Buss and colleagues investigated the speech discrimination score in the presence of speech and continuous noises for children aged 5–10 years and adults 18–41 years. Their findings displayed that the scores of both groups were lower in the presence of speech noise than continuous noise, and both speech noise and the speaker's speech characteristics affect the obtained scores. They reported that the type of mask has a significant effect on word recognition ability in competitive conditions, and the more similar the frequency spectrum of the speaker's voice and the speech masker sound, the poorer the word discrimination performance will be [14].

Petley and colleagues reported that children who have normal hearing thresholds in pure tone audiograms and have difficulty understanding speech in noise are suspected of having cognitive impairment and central auditory processing disorders. Therefore, they are in the category of subclinical hearing loss, and it is necessary for all children who have problems understanding speech in the presence of noise to be diagnosed by school healthcare workers, teachers, or children's parents through specialized speech comprehension tests [15]. Dubas et al investigated the performance of word recognition and discrimination in noise in preschool children. Their findings showed that the age factor and the characteristics of the words have a direct effect on the obtained scores. As the age of the child increases and the difficulty of the words decreases, the performance of speech recognition and discrimination improves [16].

In total, the normal values of the WINP test for children, which were obtained based on our research, can be used in the diagnosis, treatment, and rehabilitation of all kinds of peripheral and central hearing damage, cognitive disorders, learning disorders, and developmental defects of the central nervous system. The limitations of this study were the age of the participating children. The WINP test requires the cooperation of the child. It cannot be implemented in age groups less than 5 years old, who do not cooperate properly in mental tests [1, 3]. Also, the low maturity of the nervous system in young children can distort the results of the WINP test [4, 6].

Conclusion

This article presented the norm values of WINP test scores for Persian speaking Iranian children aged 5 to 13 years. The norm of WINP test scores in the age group of 5–7 years was lower than in the age groups of 7–13 years. The biggest change in the performance of speech perception in noise was observed in the age range of 7–9 years.

Abbreviations

WINP Word-in-noise perception test
HMWs Homtonic-monosyllabic words

Supplementary Information

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Additional file 1: 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 [1, 2, 4].

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Authors' contributions

SFE was the project designer, data analyst, and author of the paper. ES was the scientific advisor of the research. NG and MM also collected the data. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available [reason why data are not public] but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the research ethics committee of Hamadan University of Medical Sciences (Code: IR.UMSHA.REC.1401.478). At the beginning of the work, the study procedure was explained to all participants and their parents signed the consent forms.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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