SUPRATHRESHOLD SPEECH RECOGNITION IN PRESCHOOL CHILDREN WITH HEARING LOSS

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Abstract

Word recognition assessment provides important information about speech perception in children with hearing loss. This study aimed to evaluate suprathreshold word recognition performance and speech presentation levels in preschool children with different types and degrees of hearing loss. A total of 58 children aged 4-6 years were included, with 116 ears analyzed. Of these, 16 ears had normal hearing, 71 conductive, 23 sensorineural, and 6 mixed hearing loss. Word recognition scores (WRS) of 90-100% were obtained in all normal-hearing ears, 90.1% of ears with conductive hearing loss, 34.8% with sensorineural hearing loss, and 33.3% with mixed hearing loss. Among ears with mild hearing loss, 91.4% achieved WRS of 90-100%, whereas none with moderate or severe hearing loss reached this range. Maximum WRS required presentation levels of 25-40 dB SL in 59% of ears with hearing loss compared with 31.3% of normal-hearing ears ($\chi^2 = 4.29$, df = 1, $p = 0.038$, $\varphi = 0.192$). These findings demonstrate poorer word recognition with greater hearing loss and increased presentation-level requirements in hearing-impaired preschool children.

Keywords: word recognition, preschool children, hearing loss

1. Introduction

Assessment of speech recognition in children is particularly important because adequate access to auditory information is essential for speech and language development, communication, and learning. Auditory deprivation may influence broader aspects of communication and cognitive development (Hasanbegovic & Cajlakovic Kurtalic, 2026). Limited access to language and communication during the early stages of development may have broader consequences for children who are deaf or hard of hearing (Paul & Hasanbegovic, 2026).

Speech audiometry evaluates a person's ability to hear and understand speech. It has been incorporated into audiological practice in multiple ways: to establish the degree of hearing loss for speech; to validate pure tone thresholds; as a reference point for supra-threshold speech tests; to determine the dynamic range for speech; to establish the most comfortable loudness level (MCL) and uncomfortable loudness level (UCL) for speech; to assess speech recognition ability (in quiet and noise); to establish gain and maximum output requirements for hearing aids; to evaluate the likelihood of success with amplification; to determine the need for aural (re)habilitation; and to assess hearing sensitivity in difficult to-test populations (Punch & Rakerd, 2026).

The most common suprathreshold measure is the word recognition score (WRS), which is generally expressed as the percentage of correctly identified words at a presentation level relative to the speech recognition or reception threshold (SRT) or an average of pure-tone thresholds (McArdle & Hnath-Chisolm, 2015). Word recognition testing provides information that complements pure-tone audiometry by demonstrating how effectively audible speech can be recognized. The words could be presented in an *open-set* format, which means that the patient must respond without any prior knowledge of what the possible alternatives might be, or a *closed-set* format, which means that the patient is provided with a choice of several possible response alternatives (Jachova & Ristovska, 2023).

Presentation level is an important procedural consideration in word recognition testing. One goal of a diagnostic evaluation is to establish how well a person understands speech when it is presented at a level high enough to be audible while still remaining within the listener's

dynamic range (Schlauch & Carney, 2018). In individuals with normal hearing, maximum word recognition is generally achieved at approximately 25-40 dB above the SRT (Stach, 2010). The relationship between percentage of correctly recognized words and presentation level is described by the performance-intensity function (Bess & Humes, 2008). In conductive hearing loss, the performance-intensity function typically shows a parallel shift toward higher presentation levels, and high recognition scores can be achieved when speech is presented at a sufficiently high level. In contrast, WRSs in sensorineural hearing loss may vary considerably depending on the degree of hearing loss (Gelfand, 2016; Probst *et al,* 2006).
Word recognition performance is also influenced by the degree and audiometric configuration of hearing loss. If speech is presented at a level sufficient to ensure audibility, individuals with mild sensorineural hearing loss are generally expected to achieve high WRSs, whereas those with severe to profound hearing loss are more likely to demonstrate substantially reduced scores (Schlauch & Nelson, 2015). Furthermore, the ability to use speech information within a particular frequency region generally decreases as the degree of hearing loss in that region increases, while audiometric configuration may additionally influence access to speech information (Hornsby *et al,* 2011).
The aim of this study was to evaluate suprathreshold word recognition performance in preschool children with different types and degrees of hearing loss and to determine the presentation level of speech stimuli required to obtain maximum WRS.

2. Methods

This prospective study included 58 children with hearing loss, 32 males (55.2%) and 26 females (44.8%), aged 4 to 6 years (mean age of 5.4 ± 0.6 years). Inclusion criteria were unilateral or bilateral hearing loss and all degrees of hearing loss. Exclusion criterion was deafness. In terms of the type of hearing loss: conductive, sensorineural, or mixed, children with only one type of hearing loss were included.

2.1. Hearing assessment

Pure tone audiometry was performed with MADSEN Astera^2 audiometer (Otometrics – Natus Sensory, USA) and circumaural Radioear DD450 headphones in sound proof booth. Hearing threshold was obtained with modified Hughson-Westlake technique for frequencies from 125 to 8000 Hz. Normal hearing was defined as thresholds ≤ 20 dB HL.

2.2. Speech threshold and suprathreshold testing

Speech audiometry was also performed with MADSEN Astera^2 audiometer. WRS was determined in quiet, with the recorded speech material: *Ristovska and Jachova Monosyllabic Test 1* and *Ristovska and Jachova Monosyllabic Test 2.* Each test contains phonetically balanced monosyllabic Macedonian words. Presentation level of speech stimuli required to obtain WRS was expressed as sensation level (SL) relative to the SRT. Speech detection threshold (SDT) and SRT were obtained with *Ristovska and Jachova Disyllabic Test 3* and *Ristovska and Jachova Disyllabic Test 4.* The categories to describe the results from the suprathreshold testing were defined similar to Kramer and Brown (2019):

- WRS 90-100% – normal/excellent word recognition ability;
- WRS 75-89% – slight degree of impairment, good word recognition ability;
- WRS 60-74% – moderate degree of impairment, fair word recognition ability;
- WRS 50-59% – poor degree of impairment, poor word recognition ability.

2.3. Statistical analysis

Statistical analysis was performed using the Chi-square test to examine the association between categorical variables. The Phi coefficient (φ) was calculated as a measure of effect size. A p-value < 0.05 was considered statistically significant.

3. Results

A total of 116 ears from 58 preschool children were included in the analysis. Forty-two children had bilateral and 16 children had unilateral hearing loss. Conductive hearing loss was the most frequent hearing-loss type, present in 40 children (69%), followed by sensorineural hearing loss in 14 children (24.1%) and mixed hearing loss in 4 children (6.9%).
In Figure 1 we described the process of obtaining word recognition scores. The first step in audiological assessment was pure tone audiometry, including air and bone conduction testing, followed by determination of SDT and SRT with disyllabic words, and the final step was suprathreshold speech recognition testing and obtaining WRS with phonetically balanced monosyllabic words.

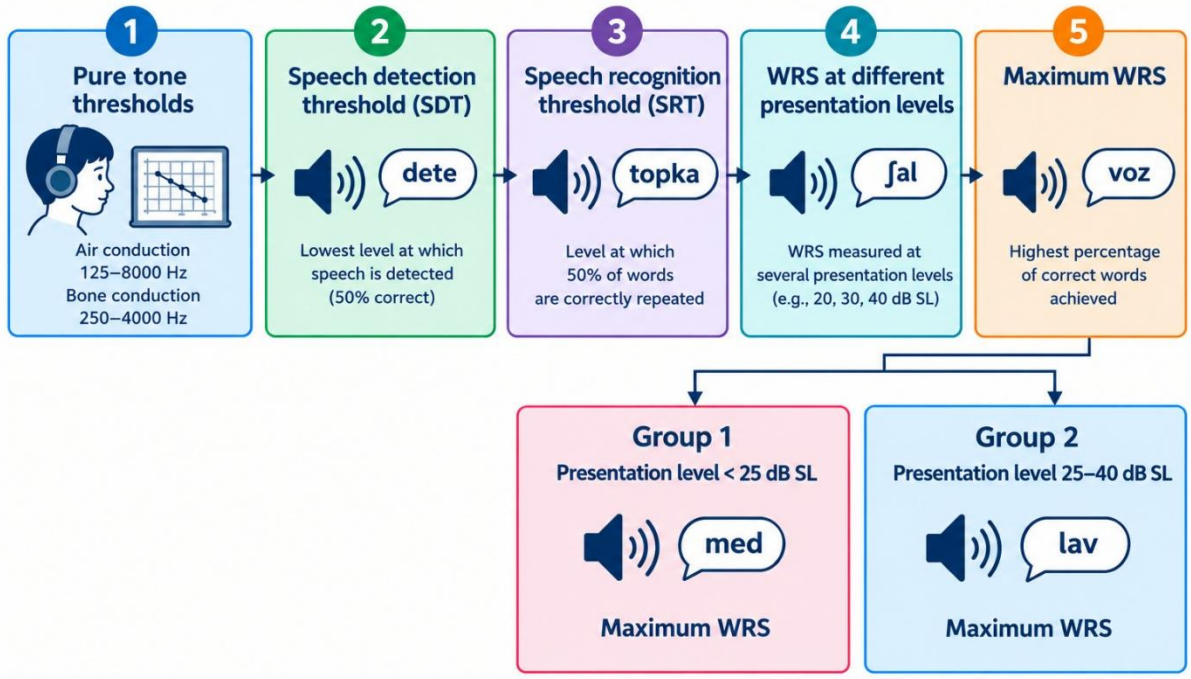


Figure 1. The process of obtaining word recognition scores

The sample contains the following Macedonian words given with International Phonetic Alphabet (IPA) symbols: dete (child), topka (ball), ʃal (scarf), voz (train), med (honey), and lav (lion). We provided translation into English in brackets.

3.1. Word recognition in relation to the type of hearing loss

Word recognition scores (WRS) of 90-100% were obtained in 90 ears (77.6%). All sixteen ears with normal in case of unilateral hearing loss achieved scores within this range. Among ears with conductive hearing loss, 64 of 71 (90.1%) achieved WRS values of 90-100%, whereas seven (9.9%) had scores below 90% (Table 1).
Lower word recognition scores were more frequent among ears with sensorineural and mixed hearing loss. In the sensorineural group, eight of 23 ears (34.8%) achieved WRS values of 90-

100%, while 15 (65.2%) had scores below 90%. Similarly, two of six ears with mixed hearing loss (33.3%) achieved scores of 90-100%, while four (66.7%) had lower scores.

Table 1. WRS in normal hearing and different type of hearing loss

WRS %	Normal hearing		Conductive		Sensorineural		Mixed		Total	
	No	%	No	%	No	%	No	%	No	%
90-100	16	13.8	64	55.2	8	6.9	2	1.7	90	77.6
75-89	/	0	7	6	8	6.9	2	1.7	17	14.7
60-74	/	0	/	0	5	4.3	1	0.9	6	5.2
50-59	/	0	/	0	2	1.7	1	0.9	3	2.6
Total	16	13.8	71	61.2	23	19.8	6	5.2	116	100

These descriptive findings indicate differences in word recognition performance across hearing-status groups, with reduced scores occurring more frequently in ears with sensorineural and mixed hearing loss than in ears with conductive hearing loss.

3.2. Word recognition in relation to the degree of hearing loss

Word recognition performance also differed according to the degree of hearing loss. Among the 81 ears classified as having mild hearing loss, 74 (91.4%) achieved WRS values of 90-100%, while seven (8.6%) had scores between 75% and 89% (Table 2).
In contrast, none of the 12 ears with moderate hearing loss or the seven ears with severe hearing loss achieved WRS values of 90-100%. Among ears with moderate hearing loss, ten (83.3%) had scores between 75% and 89%, and two (16.7%) had scores between 60% and 74%. Among ears with severe hearing loss, four (57.1%) had scores between 60% and 74%, while three (42.9%) had scores between 50% and 59%.
These findings demonstrate a clear descriptive pattern in which lower WRS values were more common in the groups with greater degrees of hearing loss.

Table 2. WRS in different degree of hearing loss

WRS %	Normal hearing		Mild		Moderate		Severe		Total	
	No	%	No	%	No	%	No	%	No	%
90-100	16	13.8	74	63.8	/	0	/	0	90	77.6
75-89	/	0	7	6	10	8.6	/	0	17	14.7
60-74	/	0	/	0	2	1.7	4	3.4	6	5.2
50-59	/	0	/	0	/	0	3	2.6	3	2.6
Total	16	13.8	81	69.8	12	10.3	7	6	116	100

3.3. Speech presentation level required to obtain maximum WRS

The presentation level required to obtain maximum WRS for all 116 ears is displayed in Table 3. Among the 16 ears with normal hearing, 11 (68.8%) achieved maximum WRS at a presentation level below 25 dB SL, while five (31.3%) required 25-40 dB SL.
Among the 100 ears with hearing loss, 41 (41%) achieved maximum WRS below 25 dB SL, whereas 59 (59%) required 25-40 dB SL. Thus, the higher presentation level was more frequently required in ears with hearing loss than in ears with normal hearing.

The Chi-square test indicated an association between hearing status and the presentation level required to obtain maximum WRS ($\chi^2 = 4.29$, df = 1, p = 0.038, $\varphi = 0.192$).
Overall, the descriptive results show that word recognition performance varied according to the type and degree of hearing loss, while a higher speech presentation level was more frequently required in ears with hearing loss than in ears with normal hearing.

Table 3. Presentation level of speech stimuli required to obtain maximum WRS

Hearing Sensitivity	< 25 dB SL		25-40 dB SL		Total	
	No	%	No	%	No	%
Normal hearing	11	9.5	5	4.3	16	13.8
Hearing loss	41	35.3	59	50.9	100	86.2
Total	52	44.8	64	55.2	116	100

Chi-square test (p = 0.038)

3.4. Presentation level required to obtain maximum WRS in different degree of hearing loss

The presentation level of speech stimuli required to obtain maximum WRS in different degree of hearing loss is displayed in Figure 2. The figure shows distribution of all 116 ears. In both subgroups (obtained WRS at presentation level < 25 dB SL or 25-40 dB SL) majority of ears had mild hearing loss.

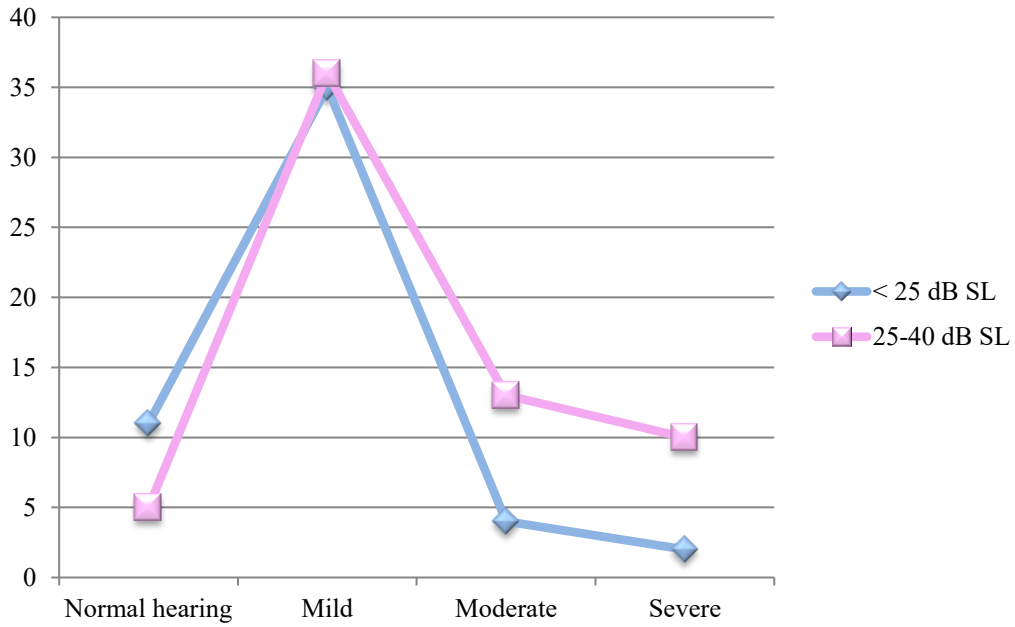


Figure 2. Number of ears according to the presentation level in different degree of hearing loss

4. Discussion

The present study evaluated suprathreshold word recognition in preschool children according to the type and degree of hearing loss and examined the presentation level required to obtain maximum WRS. The findings showed generally high word recognition performance in ears with normal hearing and conductive hearing loss, whereas reduced scores were more frequent in sensorineural and mixed hearing loss. Word recognition also decreased with increasing degree of hearing loss. In addition, ears with hearing loss more frequently required higher speech presentation levels to achieve maximum WRS.

All normal-hearing ears achieved WRSs of 90-100%. High scores were also obtained in the majority of ears with conductive hearing loss, with 90.1% achieving WRSs of 90-100%. This finding is consistent with the expected speech recognition characteristics of conductive hearing loss. The performance-intensity function in conductive hearing loss generally demonstrates a parallel shift toward higher sound levels, with high levels of speech recognition achieved when the speech signal is sufficiently audible (Probst *et al,* 2006). Nevertheless, chronic conductive hearing loss may be associated with speech intelligibility deficits even in individuals with normal bone-conduction thresholds (Okada *et al,* 2020).

Although it is generally expected that normal or near-normal word recognition can be achieved during suprathreshold testing in conductive hearing loss when speech is presented at a sufficiently high level (Probst *et al,* 2006), this was not observed in all children with conductive hearing loss in the present study. Seven ears (9.9%) had WRSs below 90%. Several factors may have contributed to these lower scores. In children with middle-ear disease, pronounced middle-ear effusion may have reduced the effective audibility and quality of the speech signal. In addition, speech audiometry in preschool children is influenced by attention, motivation, understanding of the task, and cooperation; therefore, reduced WRS in an individual child may not necessarily reflect auditory dysfunction alone. These factors were not specifically evaluated in the present study and should therefore be considered possible explanations rather than established causes.

In this context, speech audiometry represents a useful component of the cross-check principle in pediatric audiological assessment. Comparison of pure-tone thresholds with speech audiometric findings may help confirm the consistency of behavioral responses and provide complementary information about functional hearing ability. This is particularly important in young children, in whom test reliability may be influenced by attention and cooperation. Thus, speech audiometry can provide a valuable cross-check of pure-tone audiometric findings across different types of hearing loss.

In contrast, only 34.8% of ears with sensorineural hearing loss and 33.3% of ears with mixed hearing loss achieved WRSs of 90-100%. WRSs in sensorineural hearing loss may range widely depending on the etiology and degree of hearing loss (Gelfand, 2016). Unlike conductive hearing loss, increasing the presentation level does not necessarily restore maximum speech recognition in sensorineural hearing loss because cochlear or neural impairment may affect the processing of speech information (Probst *et al,* 2006). The present results therefore support the clinical value of suprathreshold speech testing as a complement to pure-tone threshold assessment. Results from previous study also showed that patients with sensorineural and mixed hearing loss have normal, good, fair, and poor word recognition ability depending of degree of hearing loss (Ristovska & Jachova, 2021).

A clear relationship was also observed between the degree of hearing loss and word recognition performance. Among ears with mild hearing loss, 91.4% achieved WRSs of 90-100%. In contrast, none of the ears with moderate or severe hearing loss achieved scores within this range. Individuals with mild sensorineural hearing loss are expected to achieve relatively high WRSs when speech is presented at a sufficiently audible level, whereas substantially lower scores are more likely in severe-to-profound hearing loss (Schlauch & Nelson, 2015). The ability to benefit from speech information within a particular frequency region generally decreases as hearing loss in that region increases, while audiometric configuration may additionally affect the use of speech information across frequencies (Hornsby *et al,* 2011). These factors may contribute to the reduction in WRS observed with increasing hearing loss in the present sample. Smith *et al.* (2024) found that, in adults, conductive hearing loss had little effect on WRSs. However, for patients with mixed hearing loss or sensorineural hearing loss, speech perception abilities decreased as the severity of the hearing loss increased.

An additional finding concerned the presentation level required to achieve maximum word recognition. Maximum WRS was obtained at 25-40 dB SL in 59.0% of ears with hearing loss, compared with 31.3% of ears with normal hearing. Conversely, 68.8% of normal-hearing ears achieved maximum WRS at presentation levels below 25 dB SL. The association between hearing status and presentation level was statistically significant ($p = 0.038$). These findings indicate that children with hearing loss may require greater sensation levels to achieve their best word recognition performance. Taking into account that for a standard Chi-square test, the observations are assumed to be independent, we have to emphasize that both ears from some children were included in the analysis. Although hearing status and word recognition performance were evaluated separately for each ear, bilateral observations from the same child may be statistically correlated because the two ears share individual factors such as age, auditory development, attention, and cooperation during testing. Therefore, the assumption of independence between observations should be considered when interpreting the statistical findings.

A presentation level of approximately 25 dB above the SRT represents a basic speech audiometric paradigm, while presentation levels of 30-40 dB SL are generally considered sufficiently audible and comfortable for many patients (Stach, 2010; Paul & Whitelaw, 2011). However, the use of a fixed sensation level does not necessarily provide maximum WRS in every individual. In sensorineural hearing loss, particularly with sloping audiometric configurations, presentation at 40 dB SL relative to the SRT may provide insufficient audibility of some higher-frequency speech cues that contribute to accurate speech recognition (Gelfand, 2016). Therefore, the presentation level used for word recognition testing should take into account the individual audiometric characteristics and the level at which maximum performance is obtained. The audibility has a great influence on speech recognition outcomes. As the speech spectrum that is audible decreases, speech intelligibility gets poorer. In cases of moderate and severe hearing loss, even when speech is well above threshold, it may not be understood due to distortion component of sensorineural hearing loss. WRS is an accurate suprathreshold measurement of speech recognition in all degrees of hearing loss (Ristovska & Jachova, 2025). The Speech Intelligibility Index (SII) predicts speech-recognition performance based on the proportion of acoustic information in the speech signal that is available to a listener. This acoustic information is quantified by the amount of audible energy in various frequency bands, weighted by the importance of that energy to the intelligibility of speech. SII does not accurately predict the performance of individual hearing-impaired listeners because it accounts for the attenuation component of hearing loss but not deficits in suprathreshold processing (distortion). There is substantial variance of word-recognition scores for listeners with similar audiograms (Margolis *et al,* 2025).

It is important not to reach UCL during testing. Guthrie and Mackersie (2009) investigating the presentation levels to maximize word recognition scores concluded that the method UCL – 5 dB resulted in the highest suprathreshold phoneme-recognition scores while avoiding loudness discomfort.

Many factors influence speech recognition testing. The word lists used for speech audiometry are developed using various criteria. Macedonian word lists used for speech audiometry in the present study were previously developed according to the criteria which are considered essential in selecting test items for measuring speech recognition, including word familiarity, phonetic balance, and homogeneity of audibility (Ristovska *et al,* 2022). Arslan and Özlüoğlu (2023) investigated the effect of lexical neighborhood on word recognition test in Turkish. The 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 neighborhood density. The study with Macedonian words showed that there were no consonant confusion patterns during

suprathreshold testing with real words. In cases of phoneme confusions, listeners replace the stimulus word with another word from the lexical neighborhood (Jachova *et al,* 2023).
From a clinical perspective, the present findings emphasize that assessment of hearing sensitivity alone does not provide complete information about a child's ability to recognize speech. Determining both maximum WRS and the presentation level at which it is achieved may provide additional information regarding functional auditory performance. This is particularly relevant in preschool children, for whom adequate speech audibility and recognition are important for communication and language development.
Auditory processing and speech recognition involve more complex processes than the simple detection of sounds, and language ability may contribute substantially to speech perception in children with hearing impairment (Hasanbegovic & Cajlakovic Kurtalic, 2026). Therefore, reduced word recognition in preschool children should not necessarily be interpreted solely in relation to the degree of hearing loss. Auditory perception may reflect a complex interaction between hearing ability, language skills, therapeutic intervention, and continuous audiological support (Hasanbegovic & Cajlakovic Kurtalic, 2026).
Given that behavioral testing of young children is challenging because their cooperation is required, special care should be taken to identify children who have permanent hearing loss that was not detected by newborn hearing screening or that occurred later in childhood in order to apply appropriate intervention (Ristovska *et al,* 2025).

5. Conclusions

Suprathreshold word recognition performance in preschool children varies according to the type and degree of hearing loss. Word recognition scores of 90-100% were obtained in all normal-hearing ears and in the majority of ears with conductive and mild hearing loss, whereas lower scores were more frequent in sensorineural and mixed hearing loss and with increasing degree of hearing loss. Children with hearing loss also more frequently required presentation levels of 25-40 dB SL to achieve maximum WRS compared with normal-hearing ears. These findings emphasize the importance of assessing not only hearing thresholds but also suprathreshold speech recognition and the presentation level required for maximum performance. Individualized assessment of word recognition may provide clinically relevant information about functional hearing abilities in preschool children and contribute to appropriate audiological management.

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