JRSR 8 (2021) 169-175

Journal of Rehabilitation Sciences and Research

Journal Home Page: jrsr.sums.ac.ir

Original Article

Lexical Effects on Spoken Word Recognition in Children with Hearing Impairment: Test-Retest Reliability of the Persian Lexical Neighborhood Tests

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ARTICLE INFO

Article History:
Received: 24/07/2021
Revised: 26/10/2021
Accepted: 19/10/2021

Keywords:
Persian lexical neighborhood tests
Spoken word recognition
Hearing loss
Cochlear implant
Children

Please cite this article as:
Oryadi-Zanjani MM, Vahab M. Lexical Effects on Spoken Word Recognition in Children with Hearing Impairment: Test-Retest Reliability of the Persian Lexical Neighborhood Tests. JRSR. 2021;8(4):169-175.

ABSTRACT

Background: The current study investigated lexical effects on the recognition of spoken words in Persian-speaking children with hearing impairment using Persian lexical neighborhood tests (PLNTs).

Methods: The research was administered as a cross-sectional study. PLNTs were performed on thirty-three pediatric hearing aid (HAs) or cochlear implant (CIs) users by sound field under spectrally degraded conditions. Thirteen 7-to-13-year-old (8 boys and 5 girls) participants completed the experiments, which were administered in a 3 × 4-m acoustic room using a sound field. The order of the tests in each session was from the lowest to the highest signal-to-noise ratios (SNRs), ranging from − 2 to 4 dB. The experiments were repeated by the same examiners under the same conditions two months later with nine of the thirteen participants.

Results: Pediatric users of HAs or CIs could not optimally recognize spoken words in noise, specifically when they had to recognize words through an auditory-only modality. There was a significant difference in the participants' SWR performance on the PMLNT-easy versus the PMLNT-hard and the PDLNT-easy versus the PDLNT-hard based on independent samples T test (P<0.001). There was a significant difference in the participants' SWR performance on the PMLNT-easy versus the PDLNT-easy and the PMLNT-hard versus the PDLNT-hard based on the independent samples T test as well (P<0.001). Accordingly, word lexical difficulty (easy/hard words) and word length (monosyllabic/disyllabic words) were the most fundamental factors having significant effects on the recognition of spoken words in children with HAs or CIs in the test/retest phases.

Conclusion: The PLNTs, as a valid assessment toolkit, can be reliably used to measure SWR performance under spectrally degraded conditions in Persian-speaking children with hearing impairment using HAs or CIs.

Introduction

Speech perception (SP) as the most direct outcome of cochlear implantation plays a fundamental role in the development of speech, language, and literacy skills in children using cochlear implants (CIs) [1]. It comprises a hierarchy of processing levels including detection of utterance (identification), discrimination of its component sounds from others (discrimination), recognition of word (spoken word recognition), and, ultimately, connecting a recognized word to its meaning (comprehension) [2]. Therefore, the evaluation of children's spoken word

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recognition (SWR) as one of the essential levels of speech perception can be clinically used to monitor the efficiency of implantation and determine appropriate interventional goals [3]. However, difficulty understanding speech in noise has remained one of the main challenges in research and clinical work related to the outcomes of pediatric cochlear implantation [1, 4-8]. Accordingly, studies on children using CIs have focused on three essential issues: developing assessment tools to measure SP, studying SP in noise, and developing interventional approaches to improve SP [1, 3, 9]. To develop effective treatment programs, it is important to determine the main issues of cochlear-implanted children's performance on SP generally and SP in noise specifically. Accordingly, standard clinical measures are needed to enable researchers to reflect the real-world performance of children [5]. The neighborhood activation model (NAM) demonstrates the relationship between word frequency and neighborhood density as the fundamental factor in SWR process [10]. Using NAM, a number of assessment tools have been developed to examine SWR in children with hearing loss [who use HAs or CIs compared to their peers with normal hearing (NH)] [3, 11-25]. Initially, two lexically controlled tests, the Lexical Neighborhood Test (LNT) and the Multisyllabic Lexical Neighborhood Test (MLNT), were developed by pioneers in this field, Kirk et al. [3, 11]. Other tests were developed in English and other languages, including Lexically Controlled Words and Sentences [15], Lexically Controlled Sentences [20], Mandarin LNT and MLN [21], Multimodal Sentences [22], Multimodal Lexical Sentence Test for Children (MLST-C) [23], Korean lexically-controlled sentences [24], and Persian Lexical Neighborhood Tests (PLNTs) [25].

Findings of on the SWR in children with HAs [23, 26], children with CIs [11-17, 19, 21, 22, 24, 26-28], and children with NH [15, 18, 20-22, 25, 26] by using lexically controlled tests can be summarized as follows: first, lexically easy words are significantly recognized more accurately than lexically hard words; second, as a lexically variable, word length influences SWR significantly (i.e. multisyllabic words were significantly recognized better than monosyllabic words); third, children's performance on SWR is enhanced by increasing the signal-to-noise ratio (SNR); and finally, hearing-impaired children's performance on SWR is influenced by the lexical difficulty of words as well as the word length similar to their peers with NH. Furthermore, as Kirk et al. showed, lexically controlled tests for measuring SWR, such as the LNT and MLNT, can be used to predict a child's ability to acquire spoken language [13]. Therefore, lexically controlled tests are clinically effective tools to assess SWR ability in children before and after cochlear implantation [13, 26].

Oryadi-Zanjani et al.'s findings on Persian-speaking children with hearing loss showed that audiovisual SWR and audiovisual sentence repetition can be considered as two clinical measures to evaluate the efficiency of sensory aids (HAs or CIs) in the children. They emphasized, however, the need to develop specific assessment tools to measure SWR and sentence repetition abilities in children [29, 30]. Oryadi-Zanjani and Zamani developed PLNTs as lexically controlled tests, namely the Persian Monosyllabic Lexical Neighborhood Test (PMLNT-easy and PMLNT-hard) and the Persian Disyllabic Lexical Neighborhood Test (PDLNT-easy and PDLNT-hard). According to their findings, the PLNTs, as a valid assessment toolkit, can be used to measure SWR performance in Persian-speaking children under spectrally degraded conditions [25].

As children with hearing disorders usually have deficiencies in speech recognition, the aim of the present study was to investigate lexical effects on SWR in Persian-speaking children with HAs or CIs using PLNTs. It was hypothesized that the performance of children with CIs or HAs on SWR would be affected by the lexical difficulty and word length under spectrally degraded conditions.

Methods

The research was administered as a cross-sectional study. Informed consent was obtained from the parents of the children participating in the study, and the research protocol was approved by the Ethics Committee of Shiraz University of Medical Sciences, Shiraz, Iran (IR.SUMS.REC.1395.S509).

Participants

Thirty-three 7-to-13-year-old children (mean=9.12), including 19 with unilateral CIs and 14 with bilateral HAs (19 boys and 14 girls), were recruited from primary schools in Shiraz, Iran, through consecutive sampling. There was no significant difference between the distribution of CIs versus HAs (χ^2=0.758, P>0.05) or between boys versus girls (χ^2=0.758, P>0.05). All participants met the following inclusion criteria: 1) spoken Persian as the primary language, 2) a bilateral symmetrical sensorineural hearing loss with pure tone average thresholds >30dB HL, 3) normal tympanometry bilaterally, 4) using oral language as the communication method pre- and post-implantation (specifically for CIs users), 5) using HAs as a trial before cochlear implantation (specifically for CIs users), 6) educated at the Soroush Rehabilitation Center in Shiraz, Iran, before entering school, and 7) no additional handicapping conditions.

Assessment Tool

PLNTs, i.e. PMLNT-easy, PMLNT-hard, PDLNT-easy, and PDLNT-hard, were used to measure SWR performance in Persian-speaking children under spectrally degraded conditions. According to Oryadi-Zanjani and Zamani's findings, the participants performed significantly better on SWR using PLNTs consisting of easy words compared to PLNTs consisting of hard words and using disyllabic compared to monosyllabic words. Moreover, their performance on SWR improved overall with increases in SNR levels [25].

Procedure

The same instructions as those listed in Oryadi-Zanjani and Zamani's study [25] were followed in examining participants. The experiments were administered at the

Hearing-Speech Lab of Soroush Rehabilitation Center in Shiraz, Iran, using a sound field. Two females, one psychologist and one teacher of hearing-impaired children, collaborated as examiners. Thirteen participants (CIs users=3; HAs users=10) completed the examination; 20 participants (CIs users=16 and HAs users=4) could not hear the words in noise at all. To measure the reliability of the outputs, the experiments were repeated by the same examiners and under the same conditions two months later with 9 of the 13 participants who agreed to take part again.

The participants' score on each subscale was calculated based on the numbers of the words repeated correctly divided by the total numbers of the words. Therefore, each participant had 20 scores. The means of the participants' scores were compared statistically through IBM SPSS version 23 software using the Wilcoxon signed-rank test and the independent samples t test at the significance level of 0.05 in terms of lexical difficulty, number of syllables, and SNR levels.

Results

The means and standard deviations of the scores of hearing-impaired children (test-retest) in the PLNTs based on SNR levels are shown in Table 1.

Spoken Word Recognition Performance in Hearing-Impaired Children

Test Phase

To investigate the effect of lexical difficulty on SWR in hearing-impaired children, participants' mean scores from the test phase (13 participants) were compared using the Wilcoxon signed-rank test; comparisons were made between the PMLNT-easy versus the PMLNT-hard and the PDLNT-easy versus the PDLNT-hard in different SNR levels. A significant difference was found in the participants' SWR performance using the PMLNT-easy and the PMLNT-hard in the SNR levels of 0, 2, and 15 dB ($P<0.05$), but no significant difference was observed in the SNR levels of -2 and 4 dB ($P>0.05$). The performance of hearing-impaired children on PMLNTs (easy/hard) was highly dependent on SNR levels (Figure 1). A significant difference was also found in the participants' SWR performance using the PDLNT-easy and the PDLNT-hard in SNR levels from -2 to 15 dB ($P<0.05$). The participants performed significantly better on the SWR using the PDLNT-easy compared to the PDLNT-hard independent from the SNR levels (Figure 1).

According to the methods used, all of the hearing-impaired children (33 participants) could successfully perform the PLNTs in the SNR level of 15 dB. Thus, there was a significant difference in the participants' SWR performance on the PMLNT-easy versus the PMLNT-hard and the PDLNT-easy versus the PDLNT-hard based on the independent-samples t test ($P<0.001$).

Retest Phase

To investigate the reliability of the results related to the effect of lexical difficulty on the SWR in hearing-impaired children, their mean scores in the retest phase (9 participants) of the PMLNT-easy versus the PMLNT-hard and the PDLNT-easy versus the PDLNT-hard in the different SNR levels were compared with the Wilcoxon signed-rank test. A significant difference was found in the participants' SWR performance using the PMLNT-easy and the PMLNT-hard in the SNR levels of 2 and 15 dB ($P<0.05$); however, no significant difference was observed in the SNR levels of -2, 0, and 4 dB ($P>0.05$) (Figure 2). Similar to the test phase, the performance of hearing-impaired children on the PMLNTs (easy/hard) was highly dependent on the SNR levels in the retest

Table 1: The scores of hearing-impaired children (test-retest) in the PLNTs based on SNR levels

Subscales	N[+]	SNR[*] (dB)	Hearing-impaired children	
			Test	Retest
			Mean (SD[#])	Mean (SD[#])
PMLNT-easy	HI^-test=13 HI-retest=9	-2	0.18 (0.11)	0.20 (0.11)
PMLNT-hard			0.15 (0.11)	0.23 (0.15)
PDLNT-easy			0.44 (0.17)	0.56 (0.13)
PDLNT-hard			0.29 (0.12)	0.35 (0.18)
PMLNT-easy		0	0.25 (0.17)	0.26 (0.11)
PMLNT-hard			0.17 (0.10)	0.23 (0.10)
PDLNT-easy			0.54 (0.17)	0.67 (0.12)
PDLNT-hard			0.35 (0.17)	0.43 (0.15)
PMLNT-easy		+2	0.34 (0.25)	0.34 (0.12)
PMLNT-hard			0.21 (0.09)	0.26 (0.14)
PDLNT-easy			0.65 (0.15)	0.75 (0.10)
PDLNT-hard			0.50 (0.13)	0.50 (0.12)
PMLNT-easy		+4	0.34 (0.16)	0.39 (0.17)
PMLNT-hard			0.29 (0.10)	0.34 (0.19)
PDLNT-easy			0.70 (0.11)	0.77 (0.15)
PDLNT-hard			0.54 (0.13)	0.58 (0.11)
PMLNT-easy	HI-test=33 HI-retest=9	+15	0.70 (0.19)	0.88 (0.06)
PMLNT-hard			0.58 (0.15)	0.76 (0.08)
PDLNT-easy			0.85 (0.18)	0.96 (0.04)
PDLNT-hard			0.71 (0.10)	0.77 (0.04)

[+] Number; [*] signal-to-noise ratio; [#] standard deviation; ^ hearing-impaired

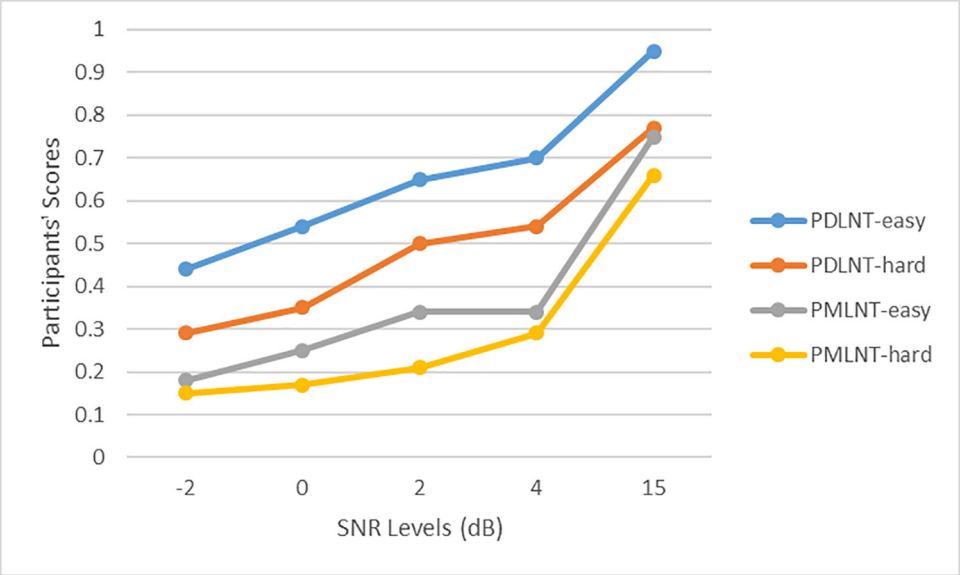

Figure 1: Comparison of hearing-impaired children's mean scores on the PLNTs in test phase

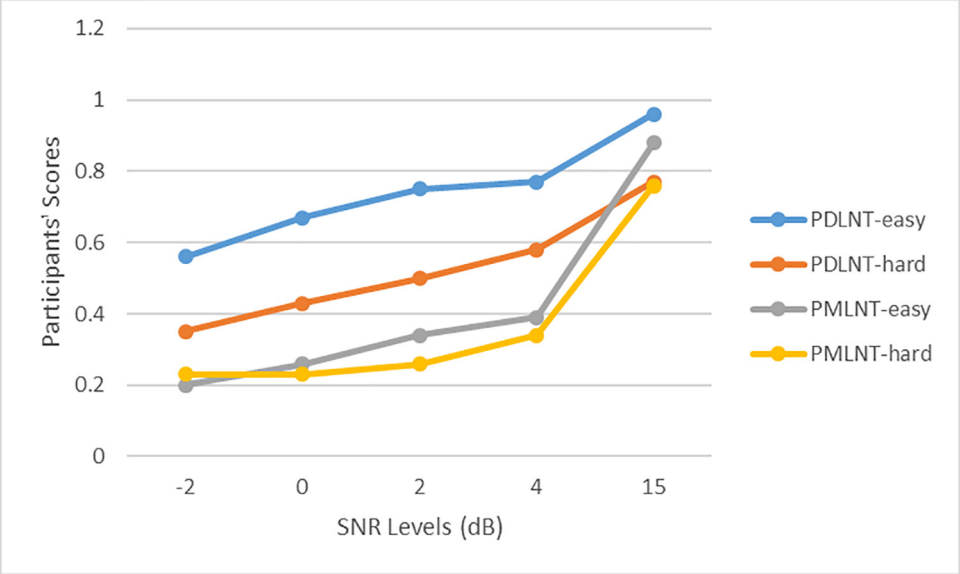

Figure 2: Comparison of hearing-impaired children's mean scores on the PLNTs in retest phase

phase. Moreover, a significant difference was found in the participants' SWR performance using the PDLNT-easy and the PDLNT-hard in SNR levels from -2 to 15 dB ($P<0.05$) (Figure 2). In sum, the results of the test phase were verified by the results of the retest phase.

Effect of Word Length on Spoken Word Recognition in Hearing-Impaired Children

Test Phase

To investigate the effect of word length on the SWR in hearing-impaired children, their mean scores in the test phase (13 participants) of the PMLNT-easy versus the PDLNT-easy and the PMLNT-hard versus the PDLNT-hard in the different SNR levels (-2 to 4 dB) were compared with the Wilcoxon signed-rank test. A significant difference was seen in the participants' SWR performance using the PMLNT-easy versus the PDLNT-easy ($P<0.05$) and the PMLNT-hard versus the PDLNT-hard ($P<0.05$) in SNR levels (Figure 1). Using the methods outlined, all of the hearing-impaired children (33 participants) could successfully perform the PLNTs in the SNR level of 15 dB. Significant differences were seen in the participants' SWR performance on the PMLNT-easy versus the PDLNT-easy and the PMLNT-hard versus the PDLNT-hard based on the independent samples t test as well ($P<0.001$) (Figure 1). Participants performed significantly better on SWR using disyllabic words compared to monosyllabic words for all stepwise increases in the SNR.

Retest Phase

To investigate the reliability of the results related to the effect of word length on the SWR in hearing-impaired children, their mean scores in the retest phase (9 participants) of the PMLNT-easy versus the PDLNT-easy and the PMLNT-hard versus the PDLNT-hard in different SNR levels (-2 to 4 dB) were compared using the Wilcoxon signed-rank test. A significant difference was seen in the participants' SWR performance using the PMLNT-easy versus the PDLNT-easy ($P<0.05$) and the PMLNT-hard versus the PDLNT-hard ($P<0.05$) in the SNR levels (Figure 2). Furthermore, according to

the methods, all of the hearing-impaired children (33 participants) could successfully perform the PLNTs in the SNR level of 15 dB. There was a significant difference in the participants' SWR performance on the PMLNT-easy versus the PDLNT-easy and the PMLNT-hard versus the PDLNT-hard based on the independent samples t test as well (P<0.001) (Figure 2). Participants performed significantly better on SWR using disyllabic words compared to monosyllabic words for all stepwise increases in the SNR. Therefore, the results of the test phase were verified by the results of the retest phase.

Effect of Signal-to-Noise Ratio Levels on Spoken Word Recognition in Hearing-Impaired Children

Test Phase

To investigate the effect of SNR level on the SWR in the hearing-impaired children, their mean scores on the PMLNT (easy/hard) and the PDLNT (easy/hard) in the test phase (13 participants) were compared across the different SNRs (-2 to 15 dB) using repeated measures ANOVA. A significant difference was found in the participants' SWR performance at different SNR levels using all the subscales, including the PMLNT-easy (P<0.001), PMLNT-hard (P<0.001), PDLNT-easy (P<0.001), and the PDLNT-hard (P<0.001). The hearing-impaired children's overall SWR performance improved by increasing the SNR levels from -2 to 15 dB (Figure 1). This improvement was similar for all stepwise increases in the SNR (P<0.001).

Retest Phase

To investigate the reliability of the results related to the SNR levels on SWR in hearing-impaired children, their mean scores on the PMLNT (easy/hard) and the PDLNT (easy/hard) in the retest phase (9 participants) were compared across the different SNRs (-2 to 15 dB) using the repeated measures ANOVA. A significant difference was found in the participants' SWR performance at different SNR levels using all the subscales, including the PMLNT-easy (P<0.001), PMLNT-hard (P<0.001), PDLNT-easy (P<0.001), and PDLNT-hard (P<0.001). The hearing-impaired children's overall SWR performance was improved by increasing the SNR levels from -2 to 15 dB (Figure 2). This improvement was similar for all stepwise increases in the SNR (P<0.001). Therefore, the results of the test phase were verified by the results of the retest phase.

Effect of Sex on Spoken Word Recognition in Hearing-Impaired Children

As shown in Table 2, the mean scores on the PLNTs in the SNR levels (-2 to 15 dB) were compared between the hearing-impaired children based on sex using the Mann-Whitney Test. No significant difference was found in spoken word recognition performance between the girls and the boys based on SNR levels (P>0.05).

Effect of Amplification Device Type on Spoken Word Recognition in Hearing-Impaired Children

As shown in Table 3, the mean scores on the PLNTs in the SNR level of 15 dB were compared between the hearing-impaired children based on the amplification device type by the Mann-Whitney Test, because the distribution of amplification device type was different among participants (CIs users=3; HAs users=10). There was no significant difference in spoken word recognition performance between children using HAs and children using CIs on the SNR (P>0.05).

Discussion

The first finding revealed that neither gender nor amplification device type (HAs/CIs) was a determinant factor for the hearing-impaired children's performance

Table 2: Comparison of differences of mean scores on PLNTs in hearing-impaired children based on sex

Sub-scales	SNR* levels															
	N+	-2 dB			0 dB			2 dB			4 dB			N	15 dB		
		Mean (SD#)		P-value	Mean (SD)		P-value	Mean (SD)		P-value	Mean (SD)		P-value		Mean (SD)		P-value
		Girl	Boy		Girl	Boy		Girl	Boy		Girl	Boy			Girl	Boy	
PMLNT-easy	Girl⁻5 Boy⁻8	0.19 (0.13)	0.18 (0.10)	>0.05	0.22 (0.09)	0.27 (0.20)	>0.05	0.25 (0.13)	0.39 (0.29)	>0.05	0.33 (0.16)	0.34 (0.16)	>0.05	Girl⁻14 Boy⁻19	0.71 (0.17)	0.70 (0.20)	>0.05
PMLNT-hard		0.11 (0.08)	0.18 (0.12)	>0.05	0.12 (0.09)	0.20 (0.10)	>0.05	0.18 (0.10)	0.23 (0.08)	>0.05	0.28 (0.07)	0.30 (0.13)	>0.05		0.58 (0.18)	0.58 (0.12)	>0.05
PDLNT-easy		0.40 (0.20)	0.46 (0.16)	>0.05	0.50 (0.18)	0.56 (0.17)	>0.05	0.63 (0.18)	0.65 (0.13)	>0.05	0.68 (0.12)	0.71 (0.11)	>0.05		0.82 (0.25)	0.87 (0.09)	>0.05
PDLNT-hard		0.30 (0.14)	0.29 (0.12)	>0.05	0.37 (0.18)	0.33 (0.18)	>0.05	0.52 (0.17)	0.48 (0.11)	>0.05	0.52 (0.12)	0.55 (0.14)	>0.05		0.72 (0.10)	0.70 (0.10)	>0.05

+Number; *signal-to-noise ratio; #standard deviation

Table 3: Comparison of differences of mean scores on PLNTs in hearing-impaired children based on amplification device type

Subscales	SNR* levels			
	N	15 dB		
		Mean (SD#)		P-value
		HA^	CI⁻	
PMLNT-easy	HA=14 CI=19	0.68 (0.15)	0.72 (0.21)	P>0.05
PMLNT-hard		0.59 (0.18)	0.58 (0.12)	P>0.05
PDLNT-easy		0.83 (0.26)	0.86 (0.08)	P>0.05
PDLNT-hard		0.74 (0.10)	0.68 (0.09)	P>0.05

+Number; *signal-to-noise ratio; #standard deviation; ^hearing aid; ~cochlear implant

on SWR. This finding was consistent with the previous findings in which there was no difference between girls' and boys' performance on SWR [12, 13, 15, 21, 31]. Additionally, considering the similar performance of children using CIs and those using HAs in the PLNTs, the current findings corresponded to Kirk et al.'s results, indicating that there is no significant difference between the percentage of key words correctly identified by children with CIs or HAs in the MLST-C [23].

The second finding revealed that there was a significant improvement in the hearing-impaired children's performance in SWR with increasing signal-in-noise thresholds, based on the PLNTs scores for all stepwise increases in the SNR (-2 to 15 dB). That is, the SNR was an essential factor influencing the ability of hearing-impaired children to recognize spoken words. It should be noted that sixteen of the twenty children using CIs could not accomplish the experiments due to their complete inability to hear words in noise. As such, the majority of the children with CIs could not recognize the spoken words in noise (SNR=-2 to 4dB). Thus, in agreement with findings from other studies, pediatric users of HAs or CIs could not optimally recognize spoken words in noise [1, 6-8, 11-13, 15, 21, 24, 26, 28], specifically when they had to recognize words through an auditory-only modality [14, 17, 18, 22, 23, 29, 30].

The third finding revealed that word lexical difficulty (easy/hard words) and word length (monosyllabic/disyllabic words) had significant effects on the recognition of spoken words in children with HAs or CIs in the test/retest phases. Thus, in accordance with previous findings [1, 11, 17, 21-23, 26-28], the current results demonstrate that pediatric HAs or CIs users' word recognition performance is influenced by both lexical properties of the stimulus words and word length. The participants' word recognition performance improved on the lexically "easy" word lists in both the monosyllabic and disyllabic stimulus words. Therefore, similar to children with NH, hearing-impaired children used: (a) structural information related to familiar words organized into similar neighborhoods in long-term memory in order to recognize spoken words [11, 25, 32, 33], and (b) length cues as well as spectral information in recognizing words due to their significantly better performance in disyllabic compared to monosyllabic word recognition [11, 25, 33].

The final finding indicated that participants' performance on the PLNTs was similar in both the test and the retest phases, suggesting that the PLNTs are a reliable toolkit for assessing SWR in Persian-speaking children using HAs or CIs. However, it is recommended that PLNTs be applied in studies with higher sample sizes to confirm the current findings.

In keeping with Oryadi-Zanjani and Zamani's findings [25], the current study primarily verified the high capability of the Persian Lexical Neighborhood Tests as a lexically controlled assessment toolkit for measuring the reliably of the real-world performance of Persian-speaking children with HAs or CIs on spoken word recognition under spectrally degraded conditions. Furthermore, similar to children with NH, the processing of SWR in children with HAs or CIs is subordinated to two essential factors, including word length and word lexical difficulty. Finally, the performance of children with HAs or CIs in recognizing spoken words is significantly declined with increases of even as much as 2 dB of noise in their environment.

Conclusion

The PLNTs, as a lexically controlled assessment toolkit, can be reliably used to measure the SWR performance under spectrally degraded conditions in Persian-speaking children with hearing impairment using HAs or CIs. Hearing-impaired children's word recognition performance is influenced by both lexical properties of the stimulus words and word length under spectrally degraded conditions.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments

The authors would like to thank Dr. Z. Shayan for her careful statistical advice and T. Lillis of AuthorAID in the Eastern Mediterranean for language editing the manuscript. Special thanks are expressed to the families and children who participated in the research.

Conflict of Interest: None declared.

References

1. Kirk KI, Hudgins M. Speech Perception and Spoken Word Recognition in Children with Cochlear Implants. In: Young NM, Kirk KI, editors. Pediatric Cochlear Implantation. USA: Springer Nature; 2016. p. 145-61.
2. Holt RF, Lalonde K. Assessing toddlers' speech-sound discrimination. Int J Pediatr Otorhinolaryngol. 2012;76(5):680-92.
3. Kirk KI, Diefendorf AO, Pisoni DB, Robbins AM. Assessing speech perception in children. USA: Indiana University, 1995.
4. Davidson LS, Geers AE, Blamey PJ, Tobey EA, Brenner CA. Factors contributing to speech perception scores in long-term pediatric cochlear implant users. Ear Hear. 2011;32(1 Suppl):19s-26s.
5. van Wieringen A, Wouters J. What can we expect of normally-developing children implanted at a young age with respect to their auditory, linguistic and cognitive skills? Hear Res. 2015;322:171-9.
6. Gifford RH, Olund AP, DeJong M. Improving speech perception in noise for children with cochlear implants. J Am Acad Audiol. 2011;22(9):623-32.
7. Eisenberg LS, Fisher LM, Johnson KC, Ganguly DH, Grace T, Niparko JK, et al. Sentence Recognition in Quiet and Noise by Pediatric Cochlear Implant Users: Relationships to Spoken Language. Otol Neurotol. 2016;37(2):e75-81.
8. Zaltz Y, Bugannim Y, Zechoval D, Kishon-Rabin L, Perez R. Listening in Noise Remains a Significant Challenge for Cochlear Implant Users: Evidence from Early Deafened and Those with Progressive Hearing Loss Compared to Peers with Normal Hearing. J Clin Med. 2020;9(5).
9. Oryadi-Zanjani MM, Hasanzadeh S, Rahgozar M, Shemshadi H, Purdy SC, Bakhtiari BM, et al. Comparing the effect of auditory-only and auditory-visual modes in two groups of Persian children using cochlear implants: a randomized clinical trial. Int J Pediatr Otorhinolaryngol. 2013;77(9):1545-50.
10. Luce PA, Pisoni DB. Recognizing Spoken Words: The Neighborhood Activation Model. Ear Hear. 1998;19(1):1-36.

11. Kirk KI, Pisoni DB, Osberger MJ. Lexical effects on spoken word recognition by pediatric cochlear implant users. Ear Hear. 1995;16(5):470-81.
12. Kirk KI, Hay-McCutcheon M, Sehgal ST, Miyamoto RT. Speech perception in children with cochlear implants: effects of lexical difficulty, talker variability, and word length. Ann Otol Rhinol Laryngol Suppl. 1998;185:79-81.
13. Kirk KI, Eisenberg LS, Martinez AS, Hay-McCutcheon M. The Lexical Neighborhood Test: Test-Retest Reliability and Inter-List Equivalency. Indiana: Indiana University, 1998.
14. Lachs L, Pisoni DB, Kirk KI. Use of Audiovisual Information in Speech Perception by Prelingually Deaf Children with Cochlear Implants: A First Report. Ear Hear. 2001;22:236-51.
15. Eisenberg LS, Martinez AS, Holowecky SR, Pogorelsky S. Recognition of lexically controlled words and sentences by children with normal hearing and children with cochlear implants. Ear Hear. 2002;23(5):450-62.
16. Eisenberg LS, Johnson KC, Martinez AS, Cokely CG, Tobey EA, Quittner AL, et al. Speech recognition at 1-year follow-up in the childhood development after cochlear implantation study: Methods and preliminary findings. Audiol Neuro-Otol. 2006;11(4):259-68.
17. Kirk KI, Hay-McCutcheon MJ, Holt RF, Gao S, Qi R, Gehrlein BL. Audiovisual Spoken Word Recognition by Children with Cochlear Implants. Audiol Med. 2007;5(4):250-61.
18. Tye-Murray N, Sommers M, Spehar B. Auditory and Visual Lexical Neighborhoods in Audiovisual Speech Perception. Trends Amplif. 2007;11:233-41.
19. Wang NY, Eisenberg LS, Johnson KC, Fink NE, Tobey EA, Quittner AL, et al. Tracking development of speech recognition: longitudinal data from hierarchical assessments in the Childhood Development after Cochlear Implantation Study. Otol Neurotol. 2008;29(2):240-5.
20. Krull V, Choi S, Kirk KI, Prusick L, French B. Lexical effects on spoken word recognition in children with normal hearing Ear Hear. 2010;31(1):102-14.
21. Wang NM, Wu CM, Kirk KI. Lexical effects on spoken word recognition performance among Mandarin-speaking children with normal hearing and cochlear implants. Int J Pediatr Otorhinolaryngol. 2010;74(8):883-90.
22. Holt RF, Kirk KI, Hay-McCutcheon M. Assessing multimodal spoken word-in-sentence recognition in children with normal hearing and children with cochlear implants. J Speech Lang Hear Res. 2011;54(2):632-57.
23. Kirk KI, Prusick L, French B, Gotch C, Eisenberg LS, Young N. Assessing Spoken Word Recognition in Children Who Are Deaf or Hard of Hearing: A Translational Approach. J Am Acad Audiol. 2012;23(6):464-75.
24. Lee Y, Sim H. Bilateral cochlear implantation versus unilateral cochlear implantation in deaf children: Effects of sentence context and listening conditions on recognition of spoken words in sentences. Int J Pediatr Otorhinolaryngol. 2020;137:110237.
25. Oryadi-Zanjani MM, Zamani A. Development of Persian Lexical Neighborhood Tests. Int J Pediatr Otorhinolaryngol. 2020;139:110406.
26. Pisoni DB. Speech perception in deaf children with cochlear implants. In: Pisoni DB, Remez RE, editors. The Handbook of Speech Perception. Malden: Blackwell Publishing; 2009. p. 494-523.
27. Liu H, Liu S, Kirk KI, Zhang J, Ge W, Zheng J, et al. Longitudinal performance of spoken word perception in Mandarin pediatric cochlear implant users. Int J Pediatr Otorhinolaryngol. 2015;79(10):1677-82.
28. Liu H, Liu S, Wang S, Liu C, Kong Y, Zhang N, et al. Effects of lexical characteristics and demographic factors on mandarin chinese open-set word recognition in children with cochlear implants. Ear Hear. 2013;34(2):221-8.
29. Oryadi-Zanjani MM, Vahab M, Bazrafkan M, Haghjoo A. Audiovisual spoken word recognition as a clinical criterion for sensory aids efficiency in Persian-language children with hearing loss. Int J Pediatr Otorhinolaryngol. 2015;79(12):2424-7.
30. Oryadi-Zanjani MM, Vahab M, Rahimi Z, Mayahi A. Audiovisual sentence repetition as a clinical criterion for auditory development in Persian-language children with hearing loss. Int J Pediatr Otorhinolaryngol. 2017;93:167-71.
31. Oryadi-Zanjani MM, Mohammadi T, Mohammadi Z, Vahab M. Predictive Factors of Language Development in Persian-speaking Children Using Cochlear Implants: A Pilot Study. JRSR. 2021;8(3):126-31.
32. Luce PA. Neighborhoods of words in the mental lexicon Bloomington, USA: Indiana University, 1986 Contract No.: 6.
33. Cluff MS, Luce PA. Similarity neighborhoods of spoken two-syllable words: retroactive effects on multiple activation. J Exp Psychol Hum Percept Perform. 1990;16(3):551-63.