Assessment of Auditory-Only and Audiovisual Word-in-Noise Recognition in Preschool-Aged Children With and Without Hearing Loss Using Lexically Controlled Tests: Optimal Execution Conditions

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Abstract

The present study had three main aims include: (I) to investigate visual-only, auditory-only, and audiovisual speech-in-noise (SiN) performance of Persian-speaking preschool-aged children with and without hearing loss (HL) using the preschool version of the Persian Lexical Neighborhood Tests (PLNTs-PV), (II) to compare visual-only, auditory-only, and audiovisual word-in-noise (WiN) performance of the children with hearing loss to their counterparts with normal hearing using the PLNTs-PV, and (III) to find the optimal execution conditions to measure auditory-only and audiovisual WiN recognition in preschool-aged children with and without HL using the PLNTs-PV as a lexically controlled test. As a cross-sectional study, the study was administered to Persian-speaking preschool-aged children with and without HL. As the children with HL had better WiN recognition performance in audiovisual stimulus mode than auditory-only one using the PLNTs-PV, they achieved audiovisual integration similar to their counterparts with NH. But, they performed auditory-only and audiovisual word recognition much poorer than those in the children with NH under spectrally degraded conditions. Therefore, we found optimal execution conditions to measure auditory-only and audiovisual SiN recognition in preschool-aged children with and without HL using lexically controlled tests.

Keywords: Lexically controlled tests; audiovisual speech perception; speech-in-noise recognition; hearing loss; Persian-speaking children

1. Introduction

Children with prelingually sensorineural hearing loss (HL), regardless of age, sex, degree of HL, laterality of HL, and type of hearing technology [hearing aids (HAs) or cochlear implants (CIs)], experience severe problems in speech perception under spectrally degraded conditions such as home, classroom, and educational environments (Benítez-Barrera et al., 2020; Bess et al., 1998; Caldwell & Nittrouer, 2013; Griffin et al., 2019; Ji et al., 2023; le Clercq et al., 2020; Moore et al., 2020; Oryadi-Zanjani, 2023; Oryadi Zanjani & Vahab, 2023; Reeder et al., 2015). As speech therapists or audiologists, we should use practical assessment tools in optimal conditions to find both the children's speech-in-noise (SiN) deficiencies and their origins precisely.

According to the findings, lexically controlled tests (LCTs) can be effectively used to assess speech recognition in children with HL (Eisenberg et al., 2002; Kirk, Diefendorf, et al., 1995; Kirk et al., 1998; Oryadi-Zanjani, 2022; Oryadi-Zanjani & Zamani, 2020) due to two main characteristics: (I) these tests are developed based on the neighborhood activation model (Luce & Pisoni, 1998) which acknowledged the relationship between word frequency and neighborhood density as the determining factors in the processing of spoken word recognition (SWR) in children with and without HL (Eisenberg et al., 2002; Kirk, Pisoni, et al., 1995; Krull et al., 2010; Oryadi-Zanjani, 2023;

Oryadi-Zanjani & Vahab, 2021; Oryadi Zanjani, 2023; Wang et al., 2010) and (II) these tests measure speech recognition in children with and without HL independent of their vocabulary and linguistic competence (Kirk et al., 2000; Oryadi-Zanjani & Vahab, 2021; Oryadi-Zanjani & Zamani, 2020).

However, LCTs should be performed under spectrally degraded conditions to eliminate the possibility of ceiling effects when testing children in quiet conditions (Krull et al., 2010; Oryadi-Zanjani & Zamani, 2020); that is, the process of selecting a stimulus word from the acoustic-phonetic representations stored in memory based on word frequency and neighborhood density (Luce & Pisoni, 1998) is precisely activated under reducing signal-to-noise ratio (SNR). Accordingly, LCTs may be the best choice to assess the SiN performance of children with HL compared to their counterparts with normal hearing (NH). According to research evidence, LCTs could effectively indicate that word lexical difficulty and word length affected the SiN performance of children with and without HL (Kirk et al., 1998; Kirk, Pisoni, et al., 1995; Krull et al., 2010; Oryadi-Zanjani, 2023; Oryadi-Zanjani & Vahab, 2021; Oryadi-Zanjani & Zamani, 2020; Oryadi Zanjani, 2023; Oryadi Zanjani & Vahab, 2023; Wang et al., 2010); that is, children with and without HL can recognize “easy” words (frequently occurrence + sparse phonologically similar neighbors) better than “hard” words (infrequently occurrence + dense phonologically similar neighbors) and disyllabic words better than monosyllabic words under spectrally degraded conditions.

Furthermore, LCTs were effectively used to compare visual-only, auditory-only, and audiovisual word and sentence in noise recognition in children with and without HL. The findings of studies on SWR using LCTs displayed that both children with and without HL achieved the highest to the lowest scores in audiovisual, auditory-only, and visual-only stimulus modes, respectively (Holt et al., 2011; Kirk et al., 2007; Lachs et al., 2001; Schorr et al., 2005); that is, the SiN performance of children with and without HL is improved by audiovisual integration during the process of SWR under spectrally degraded conditions. Interestingly, this important finding has been confirmed using non-lexically controlled tests under quiet conditions in children with and without HL who speak different languages, such as English (Bergeson et al., 2005; Lachs et al., 2001), Mandarin (Tsao, 2019), and Persian (Oryadi-Zanjani et al., 2015; Oryadi-Zanjani et al., 2017).

However, we found no studies comparing auditory-only and audiovisual SiN performance between children with and without HL using LCTs. WiN performance in auditory-only and audiovisual stimulus modes was compared between children with and without HL using a non-lexically controlled test that included monosyllabic meaningful and nonsense words at 0 dB SNR (Taitelbaum-Swead & Fostick, 2017). The findings of this study showed that children with HL had poorer word-in-noise (WiN) recognition in auditory-only and audiovisual stimulus modes than children with NH. However, some studies reported that children with HL performed better in visual-only stimulus mode than those with NH (Holt et al., 2011; Stevenson et al., 2017; Taitelbaum-Swead & Fostick, 2017).

In conclusion, it is essential to compare the SiN performance of children with HL to those of counterparts with NH in visual-only, auditory-only, and audiovisual using LCTs under spectrally degraded conditions. Therefore, the present study had three main aims include: (I) to investigate visual-only, auditory-only, and audiovisual SiN performance of Persian-speaking preschool-aged children with and without HL using the preschool version of the Persian Lexical Neighborhood Tests (PLNTs-PV) (Oryadi Zanjani, 2023; Oryadi Zanjani & Vahab, 2023), (II) to compare visual-only, auditory-only, and audiovisual SiN performance of the children with HL to those with NH using the PLNTs-PV, and (III) to find the optimal execution conditions to measure auditory-only and audiovisual WiN recognition in preschool-aged children with and without HL using the PLNTs-PV as a lexically controlled test. Accordingly, there were three hypothesizes: (I) the children with and without HL may achieve the highest to the lowest scores in audiovisual, auditory-only, and visual-only stimulus modes of the PLNTs-PV, respectively, (II) auditory-only and audiovisual SiN performance of the children with HL may be poorer than their counterparts with NH, but both children with and without HL may have similar performance in visual-only conditions, and (III) the difference between the SiN performance of children with and without HL may be distinctive using some subscales of the PLNTs-PV at one or more specific SNR levels.

2. 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 (the approval number: IR.SUMS.REHAB.REC.1401.014). The aim was to compare the SiN performance of preschool-aged children with HL and their counterparts with NH using the PLNTs-PV in three stimulus modes, including visual-only, auditory-only, and audiovisual.

2.1 Participants

2.1.1 Children with hearing loss

Seventeen 5-to-6-year-old children with HL [(five years = 8, six years = 9) (female = 11, male = 6) (unilateral CIs = 12, bilateral HAs = 5)] were recruited through convenient sampling from Soroush Rehabilitation Center for Children with Hearing Loss, Shiraz, Iran. The inclusion criteria included: spoken Persian as the primary language, a bilateral symmetrical sensorineural HL with pure tone average thresholds >30 dB HL, normal tympanometry bilaterally, using oral language as a communication method pre- and post-implantation, using HAs as a trial before cochlear implantation, educated at the Soroush Rehabilitation Center for Children with Hearing Loss, and no additional handicapping conditions.

2.1.2 Children with normal hearing

Sixty-two 4-to-6-year-old children with NH [(four years = 20, five years = 21, six years = 21) (female = 36, male = 26)] were recruited through convenient sampling from a preschool center in Shiraz, Iran. The inclusion criteria included: age, gender, Persian-speaking, normal hearing thresholds, regular communication, speech skills, language skills, and no additional handicapping conditions. Each child's health status was verified according to the child's preschool health case and the teacher/parent's report.

2.2 Assessment tool

The preschool version of the PLNT (PLNTs-PV) includes the Persian Monosyllabic Lexical Neighborhood Tests (PMLNT-easy [10 words] and PMLNT-hard [10 words]) and the Persian Disyllabic Lexical Neighborhood Test (PDLNT-easy [10 words] and PDLNT-hard [10 words]). The PLNTs-PV, as a lexically controlled assessment toolkit, can measure speech-in-noise recognition in Persian-speaking preschool-aged children (Oryadi Zanjani, 2023).

2.3 Procedure

The experiments for the children with HL were administered using a sound field at the Hearing-Speech Lab of the Soroush Rehabilitation Center for Children with Hearing Loss. Two PC speakers were fixed in the center position near the PC on a table. The sound intensity of the speakers was set at the maximum, and the excellent power of the system (Realtek Digital Output) was set at 65 dB. The experiments for the children with NH were administered using headphones at a preschool center because there was no adjusted acoustic room. Microsoft PowerPoint software was used to present the stimuli through a PC or Laptop. Concerning floor or ceiling effects on the children's performance, the three SNRs were determined to include 0, 4, and 15 dB. The experiments included 28 stages: stages X1-X4 (visual-only), stages X5-X16 (auditory-only), and stages X17-X28 (audiovisual), respectively (Table 1).

Table 1: The characteristics of the experiments' stages

Stimulus mode	SNR (dB)	PDLNT-easy	PMLNT-easy	PDLNT-hard	PMLNT-hard
Visual-only	---	X1	X2	X3	X4
Auditory-only	0	X5	X8	X11	X14
	4	X6	X9	X12	X15
	15	X7	X10	X13	X16
Audiovisual	0	X17	X20	X23	X26
	4	X18	X21	X24	X27
	15	X19	X22	X25	X28

First, a training pretest was administered using eight practice words in the 4 dB SNR through auditory modality, including two monosyllabic easy, two monosyllabic hard, two disyllabic easy, and two disyllabic hard. Two trained undergraduate students administered the experiments as the examiners. Examiner 1 sat near the participant to carry out each test on the PC or Laptop. She played each auditory, visual, or audiovisual file, and then the participant should repeat the word. Examiner 2 sat behind the children to transcript what was repeated by them. Each test item was played once but repeated one more time if needed. A short rest took after each subtest. The test was stopped after five consecutive or ten failures to replicate the words to prevent any adverse psychological effects on the children. The children's scores on each subscale were calculated based on the number of words repeated correctly divided by the total number of words. The data were analyzed using IBM SPSS version 23.

3. Results

3.1 Comparison of visual-only, auditory-only, and audiovisual speech-in-noise scores within groups

3.1.1 Comparison of auditory-only versus audiovisual speech-in-noise scores within children with and without hearing loss

The children's mean scores of the PLNTs-PV subscales under auditory-only conditions in 0, 4, and 15 dB SNR were compared to audiovisual ones within the two groups by the Independent-Samples T-Test (Table 2). Accordingly, we found that: (I) the children with HL had significantly higher scores in the PLNTs-PV subscales under audiovisual conditions than auditory-only ones in most of the SNRs throughout the experiments, except using the PDLNT-easy in 15 dB SNR and (II) the children with NH had significantly higher scores in the PLNTs-PV subscales under audiovisual conditions than auditory-only ones in most of the SNRs throughout the experiments, except using the PDLNT-easy and the PMLNT-hard in 15 dB SNR; that is, the audiovisual SiN performance of the children with and without HL were much better than their auditory-only SiN scores under spectrally degraded conditions (Figure 1).

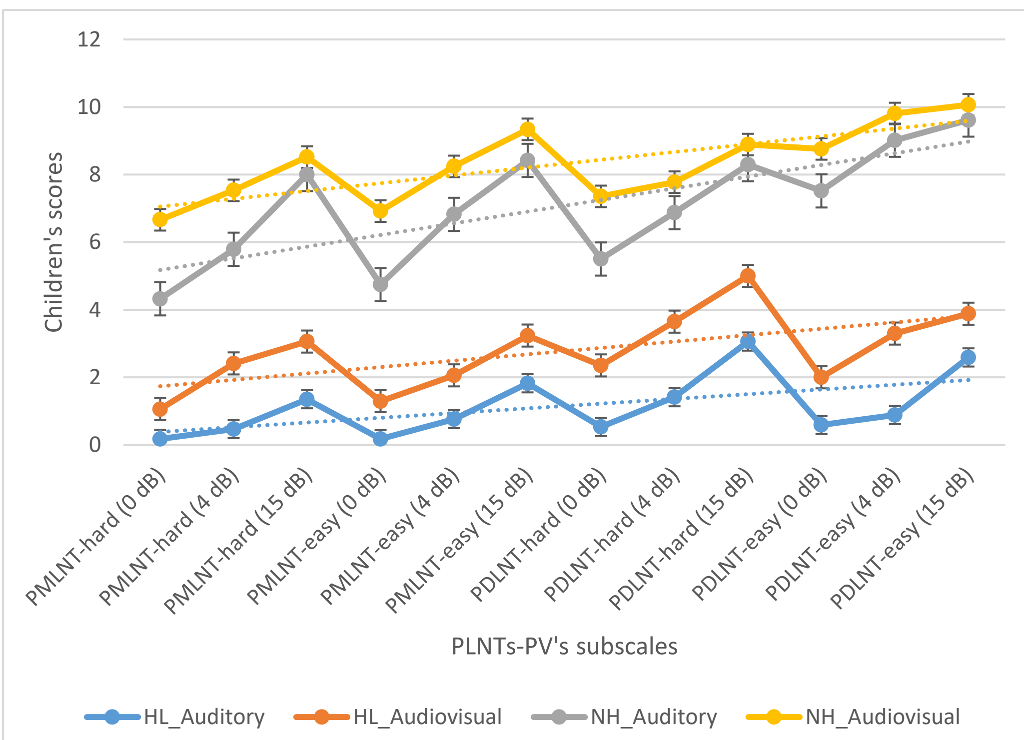

Figure 1: Auditory-only and audiovisual speech-in-noise scores in children with and without hearing loss by SNR levels

Table 2: Comparison of auditory-only and audiovisual speech-in-noise scores within children with and without hearing loss by SNR levels

					Auditory-only	Audiovisual	
Group	Lexical difficulty	Word length	SNR (dB)	N	Mean (S.D)	Mean (S.D)	*P*
Hearing loss	Easy	Mono	0	17	0.176 (0.392)	1.294 (1.311)	< 0.01
			4	17	0.764 (0.831)	2.058 (1.477)	< 0.01
			15	17	1.823 (1.424)	3.235 (2.016)	< 0.05
		Di	0	17	0.588 (1.064)	2.000 (2.121)	< 0.05
			4	17	0.882 (0.927)	3.294 (2.519)	< 0.01
			15	17	2.588 (2.237)	3.882 (2.204)	> 0.05
	Hard	Mono	0	17	0.176 (0.528)	1.058 (1.248)	< 0.05
			4	17	0.470 (0.799)	2.411 (1.872)	< 0.01
			15	17	1.352 (1.320)	3.058 (1.983)	< 0.01
		Di	0	17	0.529 (0.874)	2.352 (1.057)	< 0.01
			4	17	1.411 (1.583)	3.647 (1.835)	< 0.01
			15	17	3.058 (2.276)	5.000 (2.622)	< 0.05
Normal hearing	Easy	Mono	0	62	4.741 (2.071)	6.919 (2.397)	< 0.01
			4	62	6.822 (2.044)	8.241 (2.309)	< 0.01
			15	62	8.419 (2.092)	9.338 (1.470)	< 0.01
		Di	0	62	7.516 (1.973)	8.758 (2.351)	< 0.01
			4	62	9.016 (2.176)	9.806 (1.555)	< 0.05
			15	62	9.612 (1.813)	10.064 (1.818)	> 0.05
	Hard	Mono	0	62	4.322 (1.998)	6.661 (1.828)	< 0.01
			4	62	5.790 (1.590)	7.532 (1.533)	< 0.01
			15	62	8.000 (1.717)	8.516 (1.533)	> 0.05
		Di	0	62	5.500 (1.956)	7.354 (1.917)	< 0.01
			4	62	6.871 (1.979)	7.774 (1.475)	< 0.01
			15	62	8.290 (1.786)	8.887 (1.403)	< 0.05

3.1.2 Comparison of visual-only versus auditory-only speech-in-noise scores within children with and without hearing loss

The children's mean scores of the PLNTs-PV subscales under visual-only conditions were compared to the average scores of auditory-only in all the SNRs within the two groups by the Independent-Samples T-Test (Table 3). Accordingly, we found that the scores of the PLNTs-PV subscales under visual-only conditions were significantly lower than those scores under auditory-only conditions in all the SNRs throughout the experiments in the children with and without HL; that is, the auditory SiN performance of the children with and without HL was much better than their visual-only SiN scores (Figure 2).

Table 3: Comparison of visual-only versus auditory-only speech-in-noise scores within children with and without hearing loss

				Visual-only	Auditory-only	
Group	Lexical difficulty	Word length	N	Mean (S.D)	Mean (S.D)	*P*
Hearing loss	Easy	Mono	17	0.176 (0.528)	0.921 (1.180)	< 0.01
		Di	17	0.823 (1.131)	1.352 (1.741)	> 0.05
	Hard	Mono	17	0.117 (0.332)	0.666 (1.051)	< 0.01
		Di	17	0.529 (0.874)	1.666 (1.956)	< 0.01
Normal hearing	Easy	Mono	62	0.500 (1.251)	6.661 (2.552)	< 0.01
		Di	62	0.629 (1.451)	8.715 (2.170)	< 0.01
	Hard	Mono	62	0.258 (1.186)	6.037 (2.328)	< 0.01
		Di	62	0.129 (0.495)	6.887 (2.216)	< 0.01

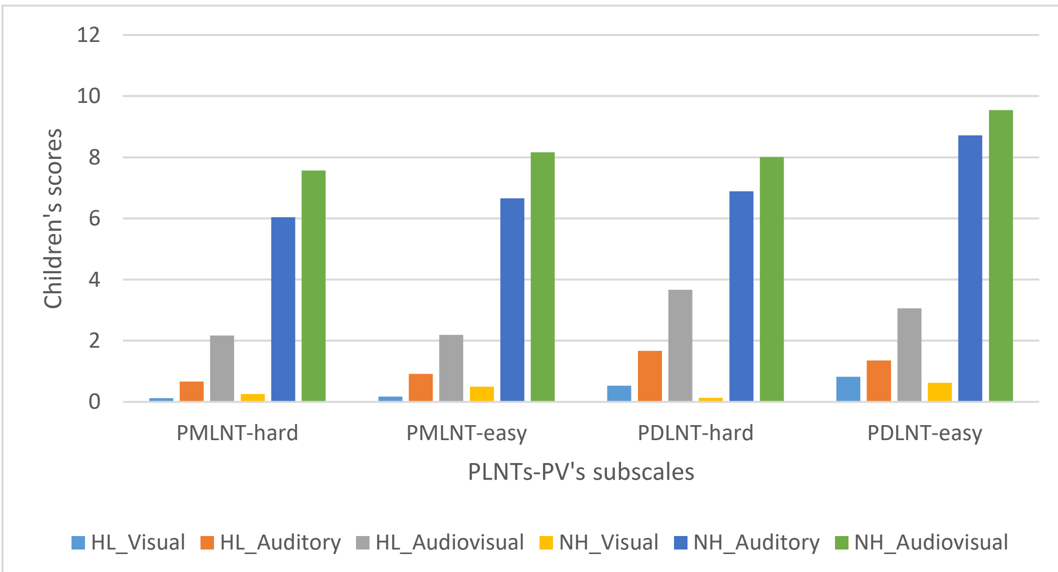

Figure 2: Visual-only, auditory-only, and audiovisual speech-in-noise scores in children with and without hearing loss

3.1.3 Comparison of visual-only versus audiovisual speech-in-noise scores within children with and without hearing loss

The children's mean scores of the PLNTs-PV subscales under visual-only conditions were compared to the average total scores of audiovisual in all the SNRs within the two groups by the Independent-Samples T-Test (Table 4). Accordingly, we found that the scores of the PLNTs-PV subscales under visual-only conditions were significantly lower than those scores under audiovisual conditions throughout the experiments in the children with and without HL; that is, the audiovisual SiN performance of the children with and without HL was much better than their visual-only SiN scores (Figure 2).

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Table 4: Comparison of visual-only versus audiovisual speech-in-noise scores within children with and without hearing loss

				Visual-only	Audiovisual	
Group	Lexical difficulty	Word length	N	Mean (S.D)	Mean (S.D)	*P*
Hearing loss	Easy	Mono	17	0.176 (0.528)	2.196 (1.789)	< 0.01
		Di	17	0.823 (1.131)	3.058 (2.378)	< 0.01
	Hard	Mono	17	0.117 (0.332)	2.176 (1.894)	< 0.01
		Di	17	0.529 (0.874)	3.666 (2.196)	< 0.01
Normal hearing	Easy	Mono	62	0.500 (1.251)	8.166 (2.313)	< 0.01
		Di	62	0.629 (1.451)	9.543 (2.008)	< 0.01
	Hard	Mono	62	0.258 (1.186)	7.569 (1.797)	< 0.01
		Di	62	0.129 (0.495)	8.005 (1.732)	< 0.01

3.2 Comparison of visual-only, auditory-only, and audiovisual speech-in-noise scores between groups

3.2.1 Comparison of auditory-only and audiovisual speech-in-noise scores between children with and without hearing loss

The children's mean scores of the PLNTs-PV subscales under auditory-only and audiovisual conditions in 0, 4, and 15 dB SNR were compared between the two groups by the Independent-Samples T-Test (Table 5). Accordingly, we found that the children with HL had significantly lower scores than those with NH in the PLNTs-PV subscales under auditory-only and audiovisual conditions in all the SNRs throughout the experiments; that is, the auditory-only and audiovisual SiN performance of the children with HL were poorer than their counterparts with NH under spectrally degraded conditions from 0 to 15 dB SNR (Figure 1).

Table 5: Comparison of auditory-only and audiovisual speech-in-noise scores between children with and without hearing loss by SNR levels

Modality	Lexical difficulty	Word length	SNR (dB)	Group	N	Mean (S.D)	*P*
Auditory-only	Easy	Monosyllabic	0	Hearing loss	17	0.176 (0.392)	< 0.01
				Normal hearing	62	4.741 (2.071)	
			4	Hearing loss	17	0.764 (0.831)	< 0.01
				Normal hearing	62	6.822 (2.044)	
			15	Hearing loss	17	1.823 (1.424)	< 0.01
				Normal hearing	62	8.419 (2.092)	
		Disyllabic	0	Hearing loss	17	0.588 (1.064)	< 0.01
				Normal hearing	62	7.516 (1.973)	
			4	Hearing loss	17	0.882 (0.927)	< 0.01
				Normal hearing	62	9.016 (2.176)	
			15	Hearing loss	17	2.588 (2.237)	< 0.01
				Normal hearing	62	9.612 (1.813)	
	Hard	Monosyllabic	0	Hearing loss	17	0.176 (0.528)	< 0.01
				Normal hearing	62	4.322 (1.998)	
			4	Hearing loss	17	0.470 (0.799)	< 0.01
				Normal hearing	62	5.790 (1.590)	
			15	Hearing loss	17	1.352 (1.320)	< 0.01
				Normal hearing	62	8.000 (1.717)	
		Disyllabic	0	Hearing loss	17	0.529 (0.874)	< 0.01
				Normal hearing	62	5.500 (1.956)	
			4	Hearing loss	17	1.411 (1.583)	< 0.01
				Normal hearing	62	6.871 (1.979)	
			15	Hearing loss	17	3.058 (2.276)	< 0.01
				Normal hearing	62	8.290 (1.786)	
Audiovisual	Easy	Monosyllabic	0	Hearing loss	17	1.294 (1.311)	< 0.01
				Normal hearing	62	6.919 (2.397)	
			4	Hearing loss	17	2.058 (1.477)	< 0.01
				Normal hearing	62	8.241 (2.309)	
			15	Hearing loss	17	3.235 (2.016)	< 0.01
				Normal hearing	62	9.338 (1.470)	
		Disyllabic	0	Hearing loss	17	2.000 (2.121)	< 0.01
				Normal hearing	62	8.758 (2.351)	
			4	Hearing loss	17	3.294 (2.519)	< 0.01
				Normal hearing	62	9.806 (1.555)	
			15	Hearing loss	17	3.882 (2.204)	< 0.01
				Normal hearing	62	10.064 (1.818)	
	Hard	Monosyllabic	0	Hearing loss	17	1.058 (1.248)	< 0.01
				Normal hearing	62	6.661 (1.828)	

		4	Hearing loss	17	2.411 (1.872)	< 0.01
			Normal hearing	62	7.532 (1.533)	
		15	Hearing loss	17	3.058 (1.983)	< 0.01
			Normal hearing	62	8.516 (1.533)	
	Disyllabic	0	Hearing loss	17	2.352 (1.057)	< 0.01
			Normal hearing	62	7.354 (1.917)	
		4	Hearing loss	17	3.647 (1.835)	< 0.01
			Normal hearing	62	7.774 (1.475)	
		15	Hearing loss	17	5.000 (2.622)	< 0.01
			Normal hearing	62	8.887 (1.403)	

3.2.2 Comparison of visual-only speech-in-noise scores between children with and without hearing loss

The children's mean scores of the PLNTs-PV subscales under visual-only conditions were compared between the two groups by the Independent-Samples T-Test (Table 6). Accordingly, there was no significant difference between the scores of visual-only conditions in the children with HL and those with NH throughout the experiments; that is, the visual-only SiN performance of the children with HL was similar to those with NH (Figure 2).

Table 6: Comparison of visual-only speech-in-noise scores between children with and without hearing loss

Lexical difficulty	Word length	Group	N	Mean (S.D)	*P*
Easy	Monosyllabic	Hearing loss	17	0.176 (0.528)	> 0.05
		Normal hearing	62	0.500 (1.251)	
	Disyllabic	Hearing loss	17	0.823 (1.131)	> 0.05
		Normal hearing	62	0.629 (1.451)	
Hard	Monosyllabic	Hearing loss	17	0.117 (0.332)	> 0.05
		Normal hearing	62	0.258 (1.186)	
	Disyllabic	Hearing loss	17	0.529 (0.874)	> 0.05
		Normal hearing	62	0.129 (0.495)	

3.3 Comparison of the differences in the PLNTs-PV subscales' scores between children with and without hearing loss in visual-only, auditory-only, and audiovisual stimulus modes

The differences in the PLNTs-PV subscales' scores of visual-only, auditory-only, and audiovisual stimulus modes were compared between children with and without HL by the Independent-Samples T-Test (Tables 7 & 8). Accordingly, the differences (D) in the PLNTs-PV subscales' scores between children with and without HL in visual-only stimulus mode were not significantly different. But, the differences in the PLNTs-PV subscales' scores were quite distinct between the two groups in auditory-only and audiovisual stimulus modes, including:

(I) Auditory-only: D1 = the PMLNT-easy minus the PDLNT-easy (0, 4 dB), D2 = the PMLNT-hard minus the PDLNT-hard (0 dB), and D4 = the PDLNT-easy minus the PDLNT-hard (0, 4, 15 dB).

(II) Audiovisual: D1 = the PMLNT-easy minus the PDLNT-easy (0 dB), D2 = the PMLNT-hard minus the PDLNT-hard (15 dB), D3 = the PMLNT-easy minus the PMLNT-hard (4 dB), and D4 = the PDLNT-easy minus the PDLNT-hard (0, 4, 15 dB).

Therefore, precisely, the difference between the PDLNT-easy and the PDLNT-hard scores of the children with HL was lower than those of the children with NH in both auditory-only and audiovisual stimulus modes under spectrally degraded conditions from 0 to 15 dB SNR (Figure 3).

Table 7: Comparison of the differences in the PLNTs-PV subscales' scores between children with and without hearing loss in visual-only stimulus mode

		HL	NH	
Difference	N	Mean (S.D)	Mean (S.D)	*P*
D1[α]	HL = 17	0.647 (1.057)	1.613 (1.243)	> 0.05
	NH = 62			
D2[β]	HL = 17	0.411 (0.795)	0.016 (0.338)	> 0.05
	NH = 62			
D3[∞]	HL = 17	0.058 (0.428)	0.274 (0.943)	> 0.05
	NH = 62			
D4[Ω]	HL = 17	0.294 (1.212)	0.419 (0.967)	> 0.05
	NH = 62			

[α] PMLNT-easy minus PDLNT-easy, [β] PMLNT-hard minus PDLNT-hard, [∞] PMLNT-easy minus PMLNT-hard, [Ω] PDLNT-easy minus PDLNT-hard

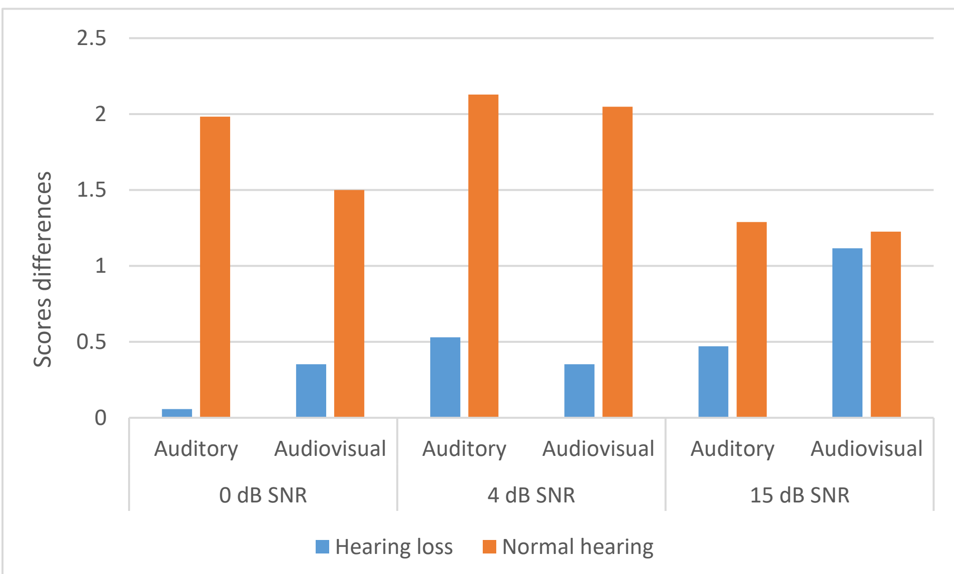

Figure 3: Difference between the PDLNT-easy and the PDLNT-hard scores in children with and without hearing loss by SNR level

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Table 8: Comparison of the differences in the PLNTs-PV subscales' scores between children with and without hearing loss in auditory-only and audiovisual stimulus modes by SNR levels

			SNR								
			0 dB			4 dB			15 dB		
			HL	NH		HL	NH		HL	NH	
Stimulus mode	Difference	N	Mean (S.D)	Mean (S.D)	*P*	Mean (S.D)	Mean (S.D)	*P*	Mean (S.D)	Mean (S.D)	*P*
Auditory-only	D1[α]	HL = 17	0.411 (0.939)	2.774 (2.220)	< 0.01	0.117 (0.696)	2.274 (2.470)	< 0.01	0.764 (1.786)	1.241 (1.575)	> 0.05
		NH = 62									
	D2[β]	HL = 17	0.352 (1.114)	1.322 (2.208)	< 0.05	1.705 (2.468)	0.371 (1.952)	> 0.05	1.705 (2.468)	0.371 (1.952)	> 0.05
		NH = 62									
	D3[∝]	HL = 17	0.000 (0.707)	0.532 (2.474)	> 0.05	0.294 (1.159)	1.064 (2.296)	> 0.05	0.470 (1.504)	0.419 (2.131)	> 0.05
		NH = 62									
	D4[Ω]	HL = 17	0.058 (0.747)	1.983 (2.479)	< 0.01	0.529 (1.230)	2.129 (2.350)	< 0.01	0.470 (2.124)	1.290 (2.067)	< 0.01
		NH = 62									
Audiovisual	D1	HL = 17	0.705 (2.023)	1.935 (2.339)	< 0.05	1.235 (2.016)	1.532 (1.956)	> 0.05	0.647 (1.966)	0.854 (1.880)	> 0.05
		NH = 62									
	D2	HL = 17	1.294 (1.447)	0.790 (2.529)	> 0.05	1.235 (1.985)	0.354 (1.775)	> 0.05	1.941 (1.951)	0.403 (1.731)	< 0.01
		NH = 62									
	D3	HL = 17	0.235 (1.480)	0.354 (2.704)	> 0.05	0.352 (2.059)	0.871 (2.153)	< 0.05	0.176 (2.068)	0.774 (1.572)	> 0.05
		NH = 62									
	D4	HL = 17	0.352 (1.902)	1.500 (2.500)	< 0.01	0.352 (1.998)	2.048 (1.885)	< 0.01	1.117 (1.866)	1.225 (1.919)	< 0.01
		NH = 62									

[α] PMLNT-easy minus PDLNT-easy, [β] PMLNT-hard minus PDLNT-hard, [∝] PMLNT-easy minus PMLNT-hard, [Ω] PDLNT-easy minus PDLNT-hard

4. Discussion

The first finding, as expected, was that the children with and without HL could recognize the spoken words of the PLNTs-PV subscales much better in audiovisual stimulus mode than auditory-only ones under spectrally degraded conditions (Figure 1). They showed the poorest SWR performance in visual-only stimulus mode (Figure 2). Accordingly, audiovisual integration facilitates SiN performance in Persian-speaking preschool-aged children with and without HL. The results were similar to the previous findings on the SiN performance of children with and without HL using LCTs (Holt et al., 2011; Kirk et al., 2007; Schorr et al., 2005). However, according to our results, the children's auditory-only and audiovisual performance was equivalent in a few conditions, including the PDLNT-easy (15 dB SNR) in children with HL and the PDLNT-easy and the PDLNT-hard (15 dB SNR) in children with NH. It may be explained that 15 dB SNR is not a challenging conditions to differentiate auditory-only and audiovisual SiN performance in children with and without HL due to ceiling effects on children's SWR performance (Krull et al., 2010).

The second finding was that the children with HL performed much poorer than their counterparts with NH on the PLNTs-PV subscales in both auditory-only and audiovisual stimulus mode under spectrally degraded conditions from 0 to 15 dB SNR (Figure 1), consistent with the previous findings (Taitelbaum-Swead & Fostick, 2017). Therefore, although audiovisual integration improved the word recognition in noise performance of children with HL using HAs or CIs, it could not help them perform similarly to their counterparts with NH. But, SWR performance on the PLNTs-PV subscales in visual-only stimulus mode was equivalent in the children with and without HL (Figure 2). This result was inconsistent with the findings of studies that reported children with HL performed better in visual-only stimulus mode than those with NH (Holt et al., 2011; Stevenson et al., 2017; Taitelbaum-Swead & Fostick, 2017). Maybe our results were due to emphasizing equivalently on visual and auditory modalities in (re)habilitation programs at the Soroush Rehabilitation Center for Children with Hearing Loss, where the children were recruited; that is, the children were trained to look at the speaker's mouth simultaneously listening to their voice. Therefore, their better performance in audiovisual stimulus mode might result from better auditory skills instead of better visual skills.

Finally, we tried to find the optimal execution conditions to measure auditory-only and audiovisual SWR in preschool-aged children with and without HL using a lexically controlled test such as the PLNTs-PV. Accordingly, the differences (D) in the PLNTs-PV subscales' scores in auditory-only and audiovisual stimulus modes were compared between the children with HL and those with NH. There was no regularly significant difference between the groups in the D1, the D2, and the D3 under spectrally degraded conditions from 0 to 15 dB SNR (Table 8). Thus, they cannot be considered optimal execution conditions to detect the difference in SiN performance of children with HL and their counterparts with NH. However, we found that the D4 was regularly different between the groups under spectrally degraded conditions (Table 8). Therefore, among the PLNTs-PV subscales, the PDLNT-easy and the PDLNT-hard can be chosen as more precise subscales to distinguish the difference in WiN recognition of children with HL and those with NH under spectrally degraded conditions from 0 to 15 dB SNR (Figure 3). Consequently, we recommend using LCTs consisting of disyllabic "easy" and "hard" words in 0 to 15 dB SNR (midpoint = 4 dB) as optimal execution conditions to measure auditory-only and audiovisual spoken word recognition in preschool-aged children with and without HL. This outcome can be explained by two preceding findings include: (I) preschool-aged children with HL could recognize spoken disyllabic words with greater accuracy than monosyllabic ones under spectrally degraded conditions (Oryadi Zanjani & Vahab, 2023) because disyllabic words have relatively less lexical neighborhood densities and more linguistic redundancy than monosyllabic words (Kirk et al., 2000), and (II) preschool-aged children with HL could recognize disyllabic hard words better than monosyllabic ones dissimilar to their equivalent performance on disyllabic and monosyllabic easy words (Oryadi Zanjani & Vahab, 2023) due to the powerful effects of lexical difficulty on children's WiN performance (Kirk, Hay-McCutcheon, Sehgal, & Miyamoto, 2000)

Concerning the limited number of children with HL in the present study, to achieve more certain outcomes, we suggest administrating the following research studies with more sample size on auditory-only and audiovisual SWR in preschool-aged and school-aged children with and without HL using LCTs under spectrally degraded conditions.

5. Conclusion

As the Persian-speaking preschool-aged children with HL had better WiN recognition performance in audiovisual stimulus mode than auditory-only one using the PLNTs-PV as a lexically controlled test, they achieved audiovisual integration similar to their counterparts with NH. But, they performed auditory-only and audiovisual word recognition much poorer than those in the children with NH under spectrally degraded conditions. Therefore, we recommend using LCTs consisting of disyllabic "easy" and "hard" words in 0 to 15 dB SNR (midpoint = 4 dB) as optimal execution conditions to measure auditory-only and audiovisual spoken word recognition in preschool-aged children with and without HL.

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