An Evaluation of Language Development and Working Memory in Children with Hearing Loss

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Abstract

Background Children with hearing loss (HL) have difficulty in performing the complex functions of language, especially in noisy environments. Cognitive processes such as working memory and short-term memory are effective on individual differences in language skills in children with HL.

Purpose The present study aimed to evaluate the vocabulary and syntax skills in language development areas and working memory of children with HL and to compare these results with those of their peers with normal hearing (NH).

Research Design In this study, a causal-comparative research model was used to measure vocabulary and syntax skills, which are among the working memory and language development skills of children with NH and those with HL.

Study Sample A total of 88 children, 44 children with HL aged 60 to 107 (months) and age- and gender-matched 44 children with NH, were included in the study.

Intervention Evaluation was made in two sessions of 20 minutes for each participant.

Data Collection and Analysis The language development and working memory of 44 children with HL and 44 children with NH were evaluated and the two groups were compared with each other. The Working Memory Scale (WMS) was used to evaluate the working memory of the participants and three subtests (vocabulary, sentence repetition, and sentence comprehension) of the Test of Language Development-Primary Fourth Edition: Turkish Version (TOLD-P:4) were used to evaluate language development. SPSS 23.0 program was used in the analysis of the data.

Results Children with HL obtained lower scores than their peers with NH in all three TOLD-P subtests. Children with HL obtained significantly lower scores in WMS verbal memory and general WMS scores compared with NH children. A positive correlation was found between WMS Verbal Memory Scores and TOLD-P sentence comprehension and sentence repetition scores. WMS Visual Memory Scores predicted the group with HL and all TOLD-P scores and Verbal Memory Scores predicted the group with NH.

Keywords
- hearing loss
- cochlear implant
- hearing aid
- language development
- working memory

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Conclusion Working memory skills are the predictor of language comprehension, reasoning, learning, literacy skills, and language development. Thus, including working memory skills as well as language skills in the education programs of children with HL contributes to the children's development.

Working memory is a dynamic system that involves the protection and modification of information through a series of interactive components including executive control and attentional resources.[1] Verbal memory is the immediate memory that involves information processing, unlike short-term memory, which is a passive temporary storage.[2] Working memory's ability to process and store information in immediate memory contributes to the development of language and academic performance as a result of both verbal and visuospatial skills.[3] In the early childhood period, which has a critical importance for the development of skills related to the processing of verbal information, this ability may be disrupted in children with severe and profound hearing loss (HL). Typical delays are observed in these children even when sensory deficit caused by HL is treated with cochlear implants (CI).[4,5]

In many studies, many demographic variables and audiological factors such as age, age of diagnosis, age of starting to use an amplification device and its duration, communication mode, and level of HL are mentioned in explaining the language development of children using CI and hearing aids (HA).[6–8] Cleary et al. (2000) stated that unexplained variance in word recognition and receptive language skills of children with HL can be explained by individual differences in verbal working memory.[9] Children with HL may experience deficits in storing and processing verbal information in working memory. These deficits affect children's vocabulary and reasoning skills.[10,11] The phonological deficit in children with HL is associated with verbal working memory, and this deficit also explains reading difficulties in these children.[12] This study aimed to compare the language development and working memory skills of children with HL with those of their peers with normal hearing (NH), with hearing thresholds less than or equal to 25 dB HL.

The hypotheses of this study are as follows:

H1: The language test results evaluating the vocabulary and syntax skills differ between children with HL and those with NH.
H2: The general results of verbal, visual working memory, and working memory differ between children with HL and those with NH.
H3: There is a relationship between age, HL diagnosis age, vocabulary, syntax skill scores, and working memory in children with HL.
H4: The Test of Language Development-Primary Fourth Edition: Turkish Version (TOLD-P) test) measurements of vocabulary, sentence repetition, sentence comprehension, and the working memory measurements of Verbal Memory and Visual Memory Scores predict the group with HL.

Materials and Methods

Participants

The causal-comparative research model was used in this study to evaluate working memory and vocabulary and syntax skills among language development skills of children with NH and children with HL.

Twenty-five children with CIs, 19 children with HA, a total of 44 children with HL who were aged 60 to 107 months and were followed up in the Otorhinolaryngology Department of Ege University Hospital were included in the study (study group). Children with HL who did not use devices regularly and those with cochlear anomalies or any additional disabilities were excluded from the study. Forty-four children with NH who visited the otorhinolaryngology clinic, who did not have additional disabilities, and who were matched with the study group in terms of age and gender (± 3 months) were included in the control group.

The Non-Interventional Clinical Research Ethics Board approved the study (GO 99166796-050.06.04/ 20-8T/36, 07.08.2020).

The mean age of the group with HL was 79.36 ± 16.34 months (HA: 81.16 ± 13.86, CI 78 ± 13.05), and the mean age of the group with NH was 79.57 ± 13.28 months. The HL diagnosis age of children using HAs was $\bar{X} = 28.95 \pm 23.29$ months (min: 3, max: 72 months); the implantation age of children with CI was $\bar{X} = 6.48 \pm 2.60$ months (min: 3, max: 14 months). CI operation age (month) of children with CIs was $\bar{X} = 21.84 \pm 10.55$ (min: 12, max: 60). Seventeen children (68%) had CI operation before the age of 24 months. The age of starting auditory–verbal education was $\bar{X} = 34.84 \pm 19.76$ months (min: 6, max: 76 months) for the group with HA and $\bar{X} = 15.84 \pm 7.67$ months (min: 6, max: 36 months) for the group with CI. Of the participants in the group with CI (25; 56.8%), 43.2% started auditory–verbal education at or before 18 months when the first words were started to be expressed. Of the 44 children with HL, 5 had consanguineous marriage history, 1 had hyperbilirubinemia, and 10 had congenital sensorineural HL history in the family. Of the participants with HA, 1 had bilateral mild HL (26–40 dB), 7 had bilateral moderate HL (41–55 dB), 6 had bilateral moderate-severe HL (56–70 dB), and 5 had bilateral severe HL (71–90). All children with HA and CI received auditory–verbal education and used only the verbal communication mode. Demographic data, which include gender, grade level, and device type of the children, are shown in ►**Table 1**.

Table 1 Demographic information of the children (*N*: 75)

	Study group		Control group	
	$\bar{X} \pm SD$	Min–Max	$\bar{X} \pm SD$	Min–Max
Age (mo)	79.36 ± 16.34	60–107	79.57 ± 13.28	60–107
Hearing loss diagnosis age (mo)	28.95 ± 23.29	3–72		
CI operation age (mo)	21.84 ± 10.55	12–60		
Age of starting auditory–verbal education				
HA	34.84 ± 19.76	6–76		
CI	15.84 ± 7.67	3–36		
Gender	*N*	%	*N*	%
Female	16	36.4		
Male	28	63.6		
Grade level				
Preschool	17	38.6	15	34.1
1st grade	12	27.3	13	29.5
2nd grade	7	15.9	8	18.2
3rd grade	6	13.6	4	9.1
4th grade	2	4.5	4	9.1
Hearing loss level of children with HA				
26–40 dB	1	5.2		
41–55 dB	7	36.8		
56–70 dB	6	31.5		
71–90 dB	5	26.3		
Hearing aid type				
Bilateral HA	19	43.2		
Bilateral CI	13	29.5		
Bimodal (HA + CI)	7	15.9		
Unilateral CI	5	11.4		

Abbreviations: CI, cochlear implant; HA, hearing aid; SD, standard deviation.

Materials

In the study, a demographic form, the TOLD-P to determine vocabulary and syntactic skills among language development skills, and the Working Memory Scale (WMS) to evaluate working memory were administered.

Demographic Form

The demographic form addresses age and educational level, among other information about children with HL, children with NH, and their families.

Test of Language Development-Primary

The Turkish validity and reliability study of TOLD-P:4 was conducted by Topbas and Guven in 2017. The TOLD-P aims to measure language development with its different dimensions in children between 4 years 0 months and 8 years 11 months and to determine the strong and weak aspects of language development. When the whole test is administered, it measures children's receptive and expressive language skills in main grammatical components. The test consists of six core subtests and three supplemental subtests. In this study, the TOLD-P Picture Vocabulary (PV), Sentence Comprehension (SC), and Sentence Repetition (SR) tests were utilized to measure the vocabulary and syntactic skills of the children. The PV subtest measures the extent to which the child understands spoken Turkish words. The SC subtest measures the child's ability to grasp the meaning of sentences. The child is expected to show the closest picture (among three pictures) to the sentence. Consisting of 36 instructions, the SR subtest measures children's ability to repeat Turkish sentences.[13]

Working Memory Scale

The WMS was developed by Ergul, Demir, Ozgur, and Yilmaz in 2017, taking the Automated Working Memory Assessment and the Working Memory Test Battery for Children as examples. The scale evaluates the working memory performances of the students up to 4th grade in verbal memory and visual memory subareas.

The verbal and visual short-term memory dimension enables the identification of children's strengths and weaknesses in working memory skills and the early identification of children with inadequate working memory skills. Verbal Short-Term Memory Dimension: In the Digit Recall subtest, children are asked to recall a series of numbers in ascending order (3–8 digits). In the Nonsense Word Recall subtest, the child is asked to repeat the nonsense words (2–6) in order.

The Verbal Working Memory dimension consists of two subtests: in the Retrieval of Digit Recall subtest, the child is asked to recall the number sequences they listen to and say them in reverse order. This subtest, which consists of an increasing number of sequences (2–6), consists of five items in total and each item consists of two trials. In the First Word Recall subtest, the child is asked to first evaluate the meaning of the sentences they listen to and then recall the first words of each sentence in order. The strings consisting of an increasing number of sentences (2–5) consist of four items in total and each item consists of two trials.

Visual Short-Term Memory Dimension: In the Pattern Matrix subtest, participants were asked to remember the squares painted in red on 5×5 squares and mark their locations on the response form. In the Block Recall subtest, the participants were asked to mark the location of the yellow block marked in different places on the figure consisting of gray color and nine blocks on the answer form at the end of the string shown for 1 second consecutively.

The Visual Working Memory dimension consists of two subtests: in the Odd-One-Out (OOO) subtest, participants are required to find the different shape among three identical shapes positioned side by side and mark the locations of the different shapes on the answer form after the successive sequence is over. It consists of six items with an increasing number of items (2–7) and each item contains two trials.

In the Spatial Discrimination subtest, the participant is required to first evaluate the same/different patterns of the star shape with the same or different patterns positioned side by side and then mark the location of the red dot positioned in different places on the star on the right on the answer form at the end of the series of consecutive demonstrations.[14]

Procedure

In the study, first, families and children who volunteered to participate in the study signed the "Informed Consent Form for Children" and they were informed about the tests to be administered. Then, the "Demographic Form" that included demographic information was filled out for each participant. The TOLD-P was administered to determine vocabulary and syntactic skills and the WMS was administered to evaluate working memory. Evaluation tools were administered in two 20-minute sessions with a break.

In the first session, TOLD-P was administered in a silent room after the Demographic Form. In the PV test of the TOLD-P, which consists of three subtests, children were asked to show the picture that best represents the meaning of the word uttered by the practitioner (out of four pictures). In the SC subtest, the second subtest, the child was asked to choose the picture that best describes the sentences.

In the Repeating Sentence subtest, the child was asked to repeat the sentence exactly as uttered by the practitioner.

The WMS test was administered in the second session.

Verbal Short-Term Memory (Digit Recall, Nonsense Word Recall), Verbal Working Memory (Back Digit Recall, First Word Recall), Visual Short-Term Memory (Pattern Matrix, Block Recall), and Visual Working Memory (Select Different, Spatial Distinguish) in the WMS test were administered sequentially. There are two trials in each of the WMS subtests. When the child did at least one of the two attempts in each item correctly, they move to the next item. When both trials were unsuccessful, that subtest was terminated and the next subtest was started. One point was given for each sequence that the children repeated or marked in the correct order.[14]

Statistical Analysis

Statistical analyses were performed using the SPSS Software version 23. The variables were investigated using visual (histogram and probability plots) and analytical methods (Kolmogorov–Smirnov test/Shapiro–Wilk test) to determine whether or not they were normally distributed. Nonparametric tests were used because the data were not normally distributed. The Mann–Whitney U test was used for comparison of two groups, and the Kruskal–Wallis test was used for comparison of more than two groups. Spearman's rho test was used for correlation between variables, and the variables that predicted the group with HL were analyzed with logistic regression analysis. A p-value less than 0.05 was accepted as statistically significant.

Results

►**Table 2** shows the comparison results of TOLD-P/PV, SC, and SR language development performances of children with HL and children with NH with the Mann–Whitney U test.

►**Table 2** shows that that the mean rank of the HL group is statistically significantly lower than the control group. According to Cohen (1988), the effect sizes were found to be smaller or smaller than the typical effect size in the PV subtest ($U = 238.500$, $p = 0.000$, $r = 0.17$), much larger than the typical effect size in the SC subtest ($U = 382.500$, $p = 0.000$, $r = 0.52$), and much larger than the typical effect size in the SR subtest ($U = 317.500$, $p = 0.000$, $r = 0.58$).

In the comparison of the TOLD-P scores of the participants with Bilateral HA, Bilateral CI, Bimodal (HA + CI), and Unilateral CI with Kruskal–Wallis analysis, only TOLD-P/PV was significantly different between the groups ($\chi 2 = 9.852$, $N = 44$, $p = 0.020$). As a result of the Mann–Whitney U test performed to determine which group the difference originated from, Bilateral CI and Bimodal (HA + CI) groups were compared ($U = 14.000$, $p = 0.27$, $r = 0.33$) and Bilateral CI and Bilateral HA groups were compared ($U = 41.500$, $p = 0.02$, $r = 0.48$) in both the mean rank of participants with Bilateral CI was statistically significantly higher than the mean rank of the participants with Bilateral HA and Bimodal (HA + CI). There was no significant difference between the other groups (►**Table 3**).

Table 2 Mann–Whitney U test results according to TOLD-P subtests of study and control groups

TOLD-P	Group	*N*	Mean rank	Sum of rank	Z	U	*p*
TOLD-P/PV	HL	44	27.92	1228.50	−6.12	238.500	0.000[a]
	NH	44	61.08	2687.50			
TOLD-P/SC	HL	44	31.18	1372.00	−4.91	382.000	0.000[a]
	NH	44	57.82	2544.00			
TOLD-P/SR	HL	44	29.72	1307.50	−5.45	317.500	0.000[a]
	NH	44	59.28	2608.50			

Abbreviations: HL, hearing loss; NH, normal hearing; PV, picture vocabulary; TOLD-P, Test of Language Development-Primary Fourth Edition: Turkish Version; SC, Sentence Comprehension; SR, Sentence Repetition.
[a]$p < 0.01$.

Table 3 Kruskal–Wallis test results according to TOLD-P subtests of study groups

TOLD-P	Group	*N*	Mean rank	Chi square	df	*p*
TOLD-P/PV	Bilateral HA	19	17.79	9.852	3	0.020[a]
	Bilateral CI	13	31.46			
	Bimodal (HA + CI)	7	18.08			
	Unilateral CI	5	22.42			
TOLD-P/SC	Bilateral HA	19	23.39	3.857	3	0.277
	Bilateral CI	13	24.08			
	Bimodal (HA + CI)	7	13.17			
	Unilateral CI	5	25.58			
TOLD-P/SR	Bilateral HA	19	22.13	0.418	3	0.937
	Bilateral CI	13	24.08			
	Bimodal (HA + CI)	7	22.28			
	Unilateral CI	5	20.17			

Abbreviations: CI, cochlear implant; HA, hearing aid; PV, Picture Vocabulary; TOLD-P, Test of Language Development-Primary Fourth Edition: Turkish Version; SC, Sentence Comprehension; SR, Sentence Repetition.
[a]$p < 0.05$.

The difference analysis of general level standard score mean ranks of verbal memory and visual memory subareas and WMS of the children with HL and children with NH was performed using the Mann–Whitney U test. ►**Table 4** shows the comparison results of the study group and control group according to the WMS subareas.

When the verbal WMS subtests of children with HL and children with NH were compared, a significant difference was found in the Verbal Memory subdomains (U = 378.500, $p = 0.00$, $r = 0.52$) with an effect size much larger than the typical effect size and in the WMS Overall score (U = 584.500, $p = 0.01$, $r = 0.34$) with an effect size greater than or equal to

Table 4 Mann–Whitney U test results by Working Memory Scale Verbal Memory, Visual Memory, and general of study and control groups

WMS	Group	*N*	Mean rank	Sum of rank	Z	U	*p*
Verbal Memory	HL	44	31.10	1368.50	−4.922	378,500	0.000[a]
	NH	44	57.90	2547.50			
Visual Memory	HL	44	43.41	1910.00	−0.401	920,000	0.688
	NH	44	45.59	2006.00			
WMS (General)	HL	44	35.78	1574.50	−3.202	584,500	0.000[a]
	NH	44	53.22	2341.50			

Abbreviations: HL, hearing loss; NH, normal hearing; WMS, Working Memory Scale.
[a]$p < 0.01$.

Table 5 Kruskal–Wallis test results by Working Memory Scale Verbal Memory, Visual Memory, and general of study groups

WMS	Group	*N*	Mean rank	Chi square	df	*p*
Verbal Memory	Bilateral HA	19	25.18	10.352	3	0.016[a]
	Bilateral CI	13	27.77			
	Bimodal (HA + CI)	7	13.75			
	Unilateral CI	5	11.33			
Visual Memory	Bilateral HA	19	23.16	2.637	3	0.451
	Bilateral CI	13	25.54			
	Bimodal (HA + CI)	7	15.58			
	Unilateral CI	5	20.75			
WMS (General)	Bilateral HA	19	24.05	7.349	3	0.062
	Bilateral CI	13	27.77			
	Bimodal (HA + CI)	7	13.75			
	Unilateral CI	5	14.92			

Abbreviations: CI, cochlear implant; HA, hearing aid; WMS, Working Memory Scale.
[a] $p < 0.05$.

the typical level according to Cohen's (1988), whereas no significant difference was found in the Visual Memory subdomains (U = 920.000, $p = 0.688$; ►**Table 5**). When the WMS scores of the participants with Bilateral HA, Bilateral CI, Bimodal (HA + CI), and Unilateral CI were compared by Kruskal–Wallis analysis, a significant difference was found between the groups only in Verbal Memory ($\chi 2 = 10.352$, $N = 44$, $p = 0.16$). As a result of the Mann–Whitney U test performed to determine which group the difference originated from, when Bilateral CI and Bimodal (HA + CI) groups were compared (U = 10.500, $p = 0.12$, $r = 0.377$), and when Bilateral CI and Unilateral CI groups were compared (U = 10.500, $p = 0.09$, $r = 0.378$), the mean rank of participants with Bilateral CI was statistically significantly higher than the mean rank of participants with Bimodal (HA + CI) and Unilateral CI. When Unilateral CI and Bilateral HA groups were compared (U = 22.500, $p = 0.28$, $r = 0.33$), the mean rank of participants with Bilateral HA was statistically significantly higher than the mean rank of participants with Bilateral HA.

It was found that there was no significant difference between the other groups. Spearman's rho test was utilized in the analysis of the relationship between age, diagnosis age of HL variables of the group with HL, TOLD-P, and WMS scores (►**Table 6**).

According to the results, a negative correlation was found between the diagnosis age of HL (month; $r = -0.32$, $p = 0.35$) variable and the TOLD-P/PV subtest ($r = -0.34$, $p = 0.26$), which according to Cohen's d (1988) is large or larger than typical effect size. There was a positive correlation between the Verbal Memory standard score ($r = 0.32$, $p = 0.35$) and SR ($r = 0.41$, $p = 0.05$) scores, whose effect size is large or larger than typical. A positive correlation was found between the Verbal Memory standard score and PV ($r = 0.34$, $p = 0.26$), SC ($r = 0.39$, $p = 0.08$), whose effect size is large or larger than typical, and SR ($r = 0.53$, $p = 0.00$), whose effect size is much

Table 6 Correlation between study group's age, diagnosis age of hearing loss, TOLD-P, and Working Memory Scale

	Variable	1	2	3	4	5	6	7
1	Age	–						
2	HL Diagnosis age	0.32[a]						
3	TOLD-P/PV	0.52[b]	0.32[a]					
4	TOLD-P/SC	−0.34[a]	−0.09	0.22				
5	TOLD-P/SR	0.49[b]	−0.18	0.36[a]	0.53[b]			
6	Verbal Memory	−0.025	0.04	0.26	0.32[a]	0.41[b]		
7	Visual Memory	0.02	0.08	0.21	0.21	0.03	0.42[b]	
8	Working Memory (General)	0.01	0.04	0.28	0.28	0.25	0.79[b]	0.80[b]

Abbreviations: HL, hearing loss; PV: Picture Vocabulary; SC, Sentence Comprehension; SR, Sentence Repetition; TOLD-P, Test of Language Development-Primary Fourth Edition: Turkish Version.
[a] $p < 0.05$.
[b] $p < 0.01$.

larger than typical. A positive correlation was found between Visual Memory standard score and SC ($r = 0.37$, $p = 0.12$), whose effect size is large or larger than typical. A positive correlation was found between WMS general score and SC ($r = 0.39$, $p = 0.09$) and SR ($r = 0.44$, $p = 0.03$), whose effect size large or larger than typical. The correlation of the relationship between WMS Verbal Memory standard score and TOLD-P/SC scores are shown in ►**Fig. 1** and its correlation with the SR scores is shown in ►**Fig. 2**.

In logistic regression analysis, the groups of children with NH and HL were the dependent group variables. Logistic regression was performed to assess whether five predictor variables (TOLD-P/PV, TOLD-P/SC, TOLD-P/S, Verbal Memory and Visual Memory Scores) significantly predicted a group with HL (the assumptions that observations were independent and that independent variables were linearly related to the logit were checked and met).

►**Table 7** present the results of the logistic regression analysis that was conducted regarding the predictor variables' predicting the group with HL. When all three predictor variables (TOLD-P/PV, TOLD-P/SC, and TOLD-P/SR) are considered together, they significantly predict whether or not a group has HL ($\chi2 = 56.484$, degree of freedom [df] $= 3$, $N = 88$, $p < 0.000$). According to the results of the analysis, while the correct classification rate of TOLD-P scores is 84% in the group with NH, this rate is 80% in the group with CI. The correct classification rate of both groups in TOLD-P scores is 82%. When all two predictor variables (WMS Verbal Vocabulary and Visual Vocabulary) are considered together, they significantly predict whether or not a group has HL ($\chi2 = 29.399$, df $= 2$, $N = 88$, $p < 0.000$). According to the results of the analysis, while the correct classification rate of working memory scores is 82% in the group with NH, this rate is 75% in the group with HL. The correct classification rate of both groups according to these scores is 78%. When examining ►**Table 7**; it is seen that all TOLD-P scores and WMS Verbal Memory Scores predicted the group with NH and WMS Visual Memory Scores predicted the group with HL.

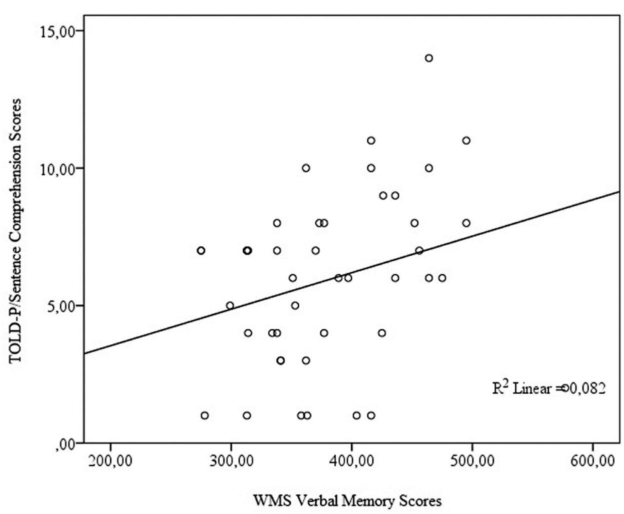

Fig. 1 Distribution of the relationship between TOLD-P/SC and WMS Verbal Memory Scores of the group with hearing loss. TOLD-P, Test of Language Development-Primary Fourth Edition: Turkish Version; SC, Sentence Comprehension; WMS, Working Memory Scale.

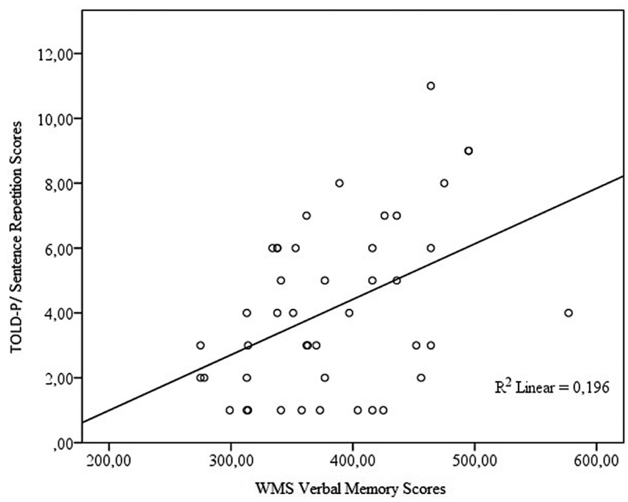

Fig. 2 Distribution of the relationship between TOLD-P/SR and WMS Verbal Memory Scores of the group with hearing loss. TOLD-P, Test of Language Development-Primary Fourth Edition: Turkish Version; SR, Sentence Repetition; WMS, Working Memory Scale.

Discussion

The aim of this study was to evaluate the language development and working memory skills of children with HL and NH and to compare these results with their NH peers. According to the results, when language development and working memory skills of children with HL and NH were compared, children with HL showed lower performance.

Hearing impairment in children with congenital HL despite early cochlear implantation and HA use affects the quality of temporal processing of acoustic stimuli.[15] Children with HL are therefore at risk for possible delays in communication, cognitive development, social development, and speech and language skills that can affect their quality of life.[16–20] The results of our study show that children with HL are behind their NH peers in syntax, vocabulary, and sentence repetition skills. According to Blamey et al., children with HL develop language skills 60% of their NH peers.[21] It is reported that almost half of the children with CIs have language skills below their peers, and that children with CIs make more syntax, vocabulary, and morphological errors and have less vocabulary than their NH peers.[22,23] CIs, HAs, and bone-anchored HAs are necessary for the development of listening, language, and literacy skills of children with HL. However, various factors such as CI, the age at which the HA is started to be used, verbal communication mode, whether they receive special education or not affect language development.[24] In our study, a negative correlation was found between the age at diagnosis of HL and vocabulary, which means that late recognition and late diagnosis of HL negatively affect vocabulary. Cupples et al. examined the language skills of 146 children with CI and HA according to audiological, cognitive, and demographic variables. They reported that the degree of HL, communication mode, and age at onset of device use predicted receptive and expressive language skills.[25] Cochlear implantation and speech therapy at an early age have been reported to contribute to the communication skills of these children.[26] In addition, it has been

Table 7 Logistic regression predicting that hearing loss groups

Variable	*B*	Standard error	Odds ratio	*p*	95.0% confidence interval for Exp(B)	
					Lower	Upper
TOLD-P/PV	−0.399	0.112	0.671	0.000	0.538	836
TOLD-P/SC	−0.154	0.130	0.857	0.236	0.664	1.106
TOLD-P/SR	−0.246	0.125	0.782	0.049	0.612	0.999
Constant	6.072	1.407	433.718	0.000		
Verbal Memory	−0.023	0.005	0.978	0.000	0.968	988
Visual Memory	0.005	0.004	1.005	0.160	0.998	1.012
Constant	6.801	2.231	899.091	0.002		

Abbreviations: PV, Picture Vocabulary; SC, Sentence Comprehension; SR, Sentence Repetition; TOLD-P, Test of Language Development-Primary Fourth Edition: Turkish Version.

reported that speech comprehension skills in noisy and quiet environments are related to language skills and demographic variables and that CI children with high language skills perform better in noisy environments.[27]

In our study, working memory skills were compared between children with HL and children with NH. In verbal memory and general working memory scores, children with HL performed lower than their peers with NH. There was no significant difference between the groups in visual memory skills. It has been reported that auditory deprivation prior to implantation in children with profound HL may cause processing deficits, especially deficits in temporal sequencing and verbal short-term memory skills.[28] Any deficit or impairment in working memory and verbal short-term memory can be gradual and lead to delays in language development.[29] Nicastri et al. reported that children with early CIs showed normal performance in attention flexibility and visuospatial working memory skills and children implanted after 12 months had difficulties in Executive Functions (EF) skills.[30] Regarding the effect of auditory deprivation on working memory skills, it was reported that children with CI scored lower in verbal and visual working memory, reasoning and vocabulary than NH children, and the difference in verbal memory was more pronounced than visual memory. In addition, children with CI have deficits in working memory that enables the storage and processing of verbal information. Even if these deficits are controlled with education, they extend to receptive language, vocabulary, and verbal reasoning.[10]

Having HA, CI, and bimodal (HA + CI) participants in the study provided the advantage of comparing language skills and working memory results. The relationship between language and working memory skills of children with CIs, HAs, and bimodal (CI + HA) users was examined. The findings showed that bilateral HA and bimodal (CI + HA) users had a lower vocabulary than participants with CIs. Välimaa et al. similarly reported that participants with bilateral HAs were 4.4 times more likely to have a poorer vocabulary than participants with CIs and reported lower performance in phonological skills.[31] The HA group in our study consisted mostly of participants with moderate to profound HL. It was thought that this might be the reason for the weaker performance compared with the CI group. On the other hand, there are studies showing that there is no difference between the groups when speech perception and language development of children with CIs and HAs are compared.[32,33] When comparing the Verbal Memory Scores of CI users with bilateral HAs and bimodal users, the Verbal Memory Scores of bilateral CI users were significantly higher than those of bimodal and unilateral CI users. Boerrigter et al. reported no difference in EF skills between CI and HA groups.[32] Jamsek et al. reported that HA users with different degrees of HL tended to show better language and EF outcomes than CI users.[34] The variability of the results may be due to heterogeneity between HA and CI groups. For future research, it is important to compare HA and CI users with larger and homogeneous sample groups.

In our study, the relationship between language skills and working memory skills was examined and a positive correlation was found between Verbal Memory subtest and TOLD-P/SC and SR subtests in the group with HL. In children with NH, positive correlations were found between Verbal Memory and TOLD-P/SC, SR, and PV subtests, between Visual Memory subtest and TOLD-P/SC subtest, and between WMS General Standard score and TOLD-P/SC and SR scale scores. According to these results, it can be said that there is a strong relationship between language skills and memory skills regardless of HL. Nittrouer et al. reported that language and literacy skills were affected by verbal working memory in both groups; phonological awareness explained the variability in verbal working memory for children with NH, whereas vocabulary was the determinant for children with CIs.[12] Similarly, Kronenberger et al. compared the verbal short-term memory and working memory, word recognition, sentence repetition, vocabulary, complex language, and comprehension skills of 66 children with CIs with NH children and reported that children with CIs showed lower performance in these skills.[35] Magimairaj and Nagaraj, looking at the relationship between auditory processing and working memory, reported that enriching auditory integration with activities such as games, music, language, and social communication would provide more benefits by optimizing attention and memory load.[36] On the other hand, traditional number sequences used to measure short-term memory capacity require encoding information and then repeating the test items using an articulatory motor response. Since most children with CIs have delayed speech development and exhibit atypical articulation and speech motor control, differences in verbal short-term memory and working memory tasks may be observed.[11,37] In our study, WMS Visual Memory Score predicted the group with HL, all TOLD-P scores and WMS verbal memory score predicted the NH group. Children with HL had more successful results in cognitive functions when visual stimuli were present. Pistav Akmese and Acarlar found that total word count scores predicted the CI group, whereas average word length and number of different words scores predicted the NH group.[22] There is a positive correlation between language development and cognitive functions and cognitive functions have been shown to predict language skills both cross-sectionally and longitudinally.[29,38,39]

Conclusion

In conclusion, early auditory deprivation due to HL may affect language and working memory skills. Language skills are related to and support each other with working memory skills in children with NH and children with HL. Early diagnosis of HL, early implantation, and early initiation of special education positively affect language and working memory skills of children with HL. It is thought that the findings of this study will contribute to the education and rehabilitation processes.

Recommendations

- It is known that children with HL have difficulties in many skills such as phonological, articulation, learning, and literacy. The relationship between these difficulties and working memory can be examined.
- Longitudinal studies can be conducted to look at the changes in the relationship between language and working memory in children with HL over time.

Conflict of Interest
None declared.

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