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Original Article

Auditory Reasoning Skills of Cochlear Implant Users

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OBJECTIVES: This study compared the auditory reasoning skills of school-going children with early and late cochlear implantation and assessed the relationship between auditory reasoning skills, language development, vocabulary knowledge, and communication skills.

MATERIALS and METHODS: In this case series study, 90 pre-lingually deaf children aged 7-10 years were assessed. Children were divided into two groups: early-implanted group with children who received cochlear implants before 3 years of age (mean, 23.45; 12-35 months) and late-implanted group with children implanted after 3 years of age (mean, 50.54; 36-84 months). Tests were performed in the auditory-visual condition. Correlational analyses were used to assess the relationships between daily communication skills, language development performances, vocabulary knowledge, and auditory reasoning skills of both the groups.

RESULTS: Auditory reasoning skills were better in the early-implanted group than in the late-implanted group (Mann–Whitney U test=518, $p<0.05$). Language performances of the early-implanted group were significantly better than those of the late-implanted group (receptive language performances: Mann–Whitney U=522, $p<0.05$; expressive language performances: Mann–Whitney U=552, $p<0.05$). Stepwise regression analysis showed that expressive language performances, vocabulary knowledge, and chronological age could predict 82% of the variance.

CONCLUSION: Reasoning skills of children with cochlear implants should be supported during the language-learning process.

KEYWORDS: Cochlear implant, children, auditory reasoning skills

INTRODUCTION

At 1 year of age, children can solve logical problems that have only one rule or step to solve. These include activities such as matching similar objects, which demonstrate that they understand the relationship between two variables. Finding solutions using three or more variables starts at 5 years of age and reaches to similar levels to adults by 11 years of age [1]. Typically-developing children can even understand and make logical assumptions using reasoning abilities in fictitious problems at 4-6 years of age [2].

A number of studies investigating reasoning skills of children who are deaf or hard of hearing have focused on non-verbal reasoning tasks and non-auditory stimulus [3, 4]. Park et al. [5] observed no significant differences with regard to non-verbal rezoning tasks between individuals who are deaf or hard of hearing and those who have normal hearing. Studies demonstrated that children who are deaf or hard of hearing used similar cognitive strategies for problem-solving as those used by typically-developing children [6, 7]. Children who are deaf or hard of hearing can develop high-level, problem-solving skills; however, it is reported that guidance is often needed [8]. Although studies from the last decade have shown the positive effects of early identification of hearing loss and early intervention strategies on language and vocabulary development [9, 10], some gaps are still observed in daily living skills. Recent studies on the long-term outcome of early cochlear implantation in children reported that difficulties in verbal reasoning skills and finding the relationships between concepts (such as size, texture, quantity) could still exist [11, 12].

Additionally, Kalback reported a significant relationship between executive functions and language performances of 6- to 14- year-old children who were deaf or hard of hearing [13]. In another study, analogical reasoning performances of adolescents who were deaf and their hearing peers were compared. The authors hypothesized that early and consistent exposure to sign language may be related to a better understanding of analogical reasoning tasks in teenagers with typical development. Teenagers with hearing impairment aged 12 and 13 performed similarly to their hearing peers in verbal analogies. However, a younger group of teenagers who were deaf and demonstrating more difficulty in some types of analogies such as part-whole, causality, and opposites than

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their hearing peers [14]. In a comprehensive review, Martin concluded that limited vocabulary knowledge and gaps in concept acquisition played an important role in the reasoning skills of children who were deaf or hard of hearing [15]. Specifically, when the complexity of the concepts increased, children who were deaf or hard of hearing found the concepts and reasoning tasks more challenging [14].

In this study, the auditory reasoning skills of school-going children were compared with those with early (before 3 years of age) and late (after 3 years of age) cochlear implantation. The main hypothesis was that late auditory access would result in auditory deprivation and would have a negative impact on auditory reasoning skills of children with cochlear implants. The second hypothesis was that language performances of children with cochlear implants would be related to their auditory reasoning performances. The third hypothesis was that the daily communication performance and vocabulary knowledge of children with cochlear implants would be concurrently essential variables for auditory reasoning skills. Lastly, we hypothesized that the auditory reasoning performances of children with cochlear implants can be significantly predicted by language skills, chronological age, and daily communication skills at each testing.

MATERIALS AND METHODS

This study protocol was approved by the Hacettepe University Non-Interventional Clinical Research Ethics Board [2015/14:299]. All procedures performed in the study followed relevant ethical guidelines, and parents of all the children enrolled in the study signed the informed consent form.

Table 1. Demographic information of the children

		Age at implantation	
		Early (n=42)	Late (n=48)
Chronological age (months)	Mean	96.33	96.58
	Range	73–121	75–119
Age at rehabilitation onset (months)	Mean	19.55	28.65
	Range	2–72	4–84
School	Mainstream	100%	83.3%
	School for the deaf	-	16.7%

Table 2. Audiological details of the enrolled children

Age at implantation		Detection of hearing loss (months)	Age at identification (months)	Age at first hearing aid use (months)
Early <3 years old	Min	1	1	3
	Mean	6.43	9.98	12
	Max	24	29	29
Late ≥3years old	Min	1	1	5
	Mean	14.46	20.02	22.31
	Max	36	52	52

Min: minimum; Max: maximum

The study included 90 children with cochlear implants, aged between 7 and 10 years. There were 42 children in early-implanted group and 48 children in late-implanted group. Performances of the early- and late-implanted groups were compared by the age at implantation. Children diagnosed with a significant physical, cognitive, and/or developmental delay and those with a significant learning disorder were excluded. At the time of testing, 21% of the children were 7 years old, 24% were 8 years old, 36% were 9 years old, and 19% were 10 years old. Females comprise 45.6% of the study population. All participants preferred communication through spoken language and spoke only Turkish.

Demographic data of the participants are provided in Table 1. Audiological data for the children are shown in Table 2.

All children regularly attended both our center's rehabilitation programs and the special education center's programs, but only two children didn't attend rehabilitation centers. The early-implanted group (mean, 19.55; range, 2-72 months) started rehabilitation programs at younger ages than those of the late-implanted group (mean, 28.65; range, 4-84 months).

Most participants started attending kindergarten and/or preschool at 6 years of age. The early-implanted group (mean, 4.24; range, 2-6 years) started kindergarten or preschool at approximately the same age as that of the late-implanted group (mean, 4.27; range, 3-6 years). However, four of the children in the late-implanted group did not attend preschool.

Functional Auditory Performance for CI questionnaire (FAPCI)

FAPCI was developed by Lin et al. [16] to evaluate daily communication performances of children with cochlear implants. It comprises 23 items, and the total score ranges between 23 and 115. The original scale demonstrated high reliability (Cronbach's α≥0.86), and total scores were significantly and positively related to the duration of cochlear implant use. The results of a pilot study on the Turkish version of FAPCI indicated very high test-retest reliability of the questionnaire (Cronbach's α=0.97) and that it could predict 67% of the daily communication performances of children with cochlear implants [17].

Turkish Version of Test of Early Language Development (TELD 3)

TELD 3 was used to assess oral language development. The internal consistency of TELD 3 ranged between 0.86 and 0.98 in both age and demographic groups [18]. Test-retest analysis of TELD 3 demonstrated excellent reliability (Cronbach's α=0.95). The construct validity of the test ranged between 0.76-0.078 when comparing the two forms and subtests by age groups. The test booklet and forms have two subtests: receptive and expressive languages.

Turkish Receptive and Expressive Language Test (TIFALDI)

TIFALDI was developed as a vocabulary subscale in Turkish language [19]. Vocabulary skills of children between 2 and 12 years of age can be assessed using this test. It has a strong test-retest reliability among all age groups (Cronbach's α=0.97). TIFALDI significantly and highly correlated with the Ankara Developmental Screening Inventory [r=0.268; p<0.05; and WISC-R (r=0.483, p<0.05]. The two subtests have two test booklets and forms: receptive and expressive vocabularies.

Selcuk Auditory Reasoning and Processing Skills Test (SIMIBT)
Based on "Test of Auditory Reasoning and Processing Skills (TARPS)," SIMIBT was adapted and modified for a Turkish population. The reliability and validity analysis of SIMIBT was reported in an unpublished thesis by Er [20]. The internal consistency of SIMIBT has been analyzed using the Kuder–Richardson 20 method, and reliability coefficients of the subtests were between 0.70-0.87. High e test-retest (r=0.90 and 0.98) and inter-rater reliability (r=0.98) were reported. Item difficulty analyses values of SIMIBT subtests were reported between 0.37 and 0.71. The construct validity of the test was reported as 0.838 as analyzed using the Kaiser–Mayer–Olkin test.

Test items were presented only in spoken language, and the children did not read the questions nor sign them. The test had 31 open-ended questions; some of them are questions and others are incomplete sentences. Correct responses were scored "1," and incorrect responses were scored "0." The results were analyzed with the total scores and subtest scores that were separately recorded. SIMIBT has six subtests: (i) General Information; (ii) Arithmetical Reasoning; (iii) Verbal Absurdities; (iv) Similarities; (v) Analogical Completions; and (vi) Causal Reasoning.

Procedures
First, the evaluation process was explained to the families and children, and informed consents were obtained from parents. The demographic information form was filled by the caregivers. Then, all children were evaluated in a quiet therapy room without any distraction. All children were allowed 10- to 15-min breaks between tests; all tests were completed on the same day. Their responses were written down in SIMIBT and TIFALDI tests, and TELD-3 forms were filled out. Lastly, FAPCI was completed by respective parents, and feedback about the child's performance was given to the parent.

Statistical Analysis
The G*Power software was used to determine the sample size and selection. According to power analysis, this study should recruit 23 individuals in each group to have 95% power with 5% type I error level to detect a minimum, clinically significant difference, when the average expected SIMIBT score in the early- and late-implanted groups is 20 and 10, respectively, with a standard deviation of 10. Additionally, the effect size of the auditory reasoning total score of both the groups is 0.42 ($r=z/\sqrt{N}$), which indicated that this study has a medium effect size.

Statistical analysis was performed using the The Statistical Package for the Social Sciences (SPSS) software version 20 (IBM Corp.; Armonk, NY, USA). Variables were investigated using visual (histograms and probability plots) and analytic methods (Shapiro–Wilk's test) to determine whether or not they are normally distributed. Descriptive analyses were presented using medians, standard deviations, and minimum and maximum values for the non-normally distributed and ordinal variables. Since language performances (TELD scores), vocabulary performances (TIFALDI scores), FAPCI scores, and auditory reasoning performances (SIMIBT scores) were not normally distributed, non-parametric tests were conducted to compare these parameters as well as to compare ordinal variables. The Mann–Whitney U test was used to compare auditory reasoning, language, vocabulary, and daily communication performances. A p-value of less than 0.05 and 0.01 was considered to show statistically significant results.

Table 3. Daily communication performances of the early- and late-implanted groups

Age at implantation	Mean	Median	SD	Minimum	Maximum
Early (n=42)	107.93	110.50	7.940	77	114
Late (n=48)	94.19	100	21.309	24	115

SD: standard deviation

RESULTS

Daily Communication Skills
Daily communication skills of both groups were assessed using FAPCI. Therefore, we used non-parametric tests for data analysis. Mann–Whitney U analysis showed a significant difference between the early- and the late-implanted groups ($U=471$, $p<0.05$). FAPCI scores were significantly higher in the early-implanted group than in the late-implanted group (Table 3). As predicted, FAPCI scores and language and vocabulary scores were significantly and highly related. Significant positive correlations were obtained between FAPCI and receptive language scores ($rs=0.665$, $p<0.01$), FAPCI and expressive language scores ($rs=0.681$, $p<0.01$), FAPCI and receptive vocabulary scores ($rs=0.556$, $p<0.01$), and FAPCI and expressive vocabulary scores ($rs=0.565$, $p<0.01$). Spearman's rho analysis revealed a moderate and significantly correlated relationship between daily communication skills and auditory reasoning skills ($rs=0.518$, $p<0.01$).

Language Performance
Language performances of the children were evaluated using the Turkish version of TELD-3. Therefore, we used non-parametric tests for data analysis. As we expected, receptive and expressive language performances in the early-implanted group were significantly better than those in the late-implanted group (receptive language performance: Mann–Whitney $U=522$, $p<0.05$; expressive language performance: Mann–Whitney $U=552$, $p<0.05$ Table 4).

Vocabulary Knowledge
Vocabulary knowledge of the children was assessed using TIFALDI in two subtests: receptive and expressive vocabularies. Receptive vocabulary scores indicated a significant difference between the early- and late-implanted groups (Mann–Whitney $U=328$, $p<0.05$), and the expressive vocabulary skills of the early and late-implanted groups were also significantly different (Mann–Whitney $U=3885$, $p<0.05$). Similar to our prediction, vocabulary skills of the early-implanted group were better than those of the late-implanted group (Table 5).

There was also a strong relationship between vocabulary performance and language performance, which is an expected result. Significantly strong correlations were found when comparing receptive language and receptive vocabulary subtests ($rs=0.70$, $p<0.01$), receptive language and expressive vocabulary subtests ($rs=0.63$, $p<0.01$), expressive language and receptive vocabulary subtests ($rs=0.69$, $p<0.01$), and expressive language and expressive vocabulary subtests ($rs=0.61$, $p<0.01$). The high correlation between TIFALDI and TEDIL scores influenced the decision to use only one subtest score from each test, which was expressive language subtest of TEDIL and receptive vocabulary subtest of TIFALDI. These tests provide similar information about language development.

Auditory reasoning performances and its relationships with other variables

Auditory reasoning performances of the children were assessed using SIMIBT, which provided scores between 0 and 31. Subtests of SIMIBT were scored as "5" if all the items were correct, with the exception of the "Causal Reasoning" subtest, which had a total maximum score of 6. The results are explained in three steps: SIMIBT total scores, SIMIBT subtest scores, and relationships with other variables.

Auditory reasoning performances of the early- and late-implanted groups

The total scores of the auditory reasoning performances of the children were significantly different between the early- and late-implanted groups (Mann–Whitney U=518; p<0.05; Table 6). These results are consistent with our main hypothesis. The results of this study showed that the early-implanted group had better scores in auditory reasoning tasks than the late-implanted group.

Although overall the performances of the early-implanted group were better in all subtests of SIMIBT than those of the late-implanted group, few children in the early-implanted group scored "0" on some of the SIMIBT subtests. Interestingly, even children who started to use their implants early and performed better on language tests or daily communication scales could still demonstrate problems in reasoning.

In the "General Knowledge" subtest, which evaluated the children's academic and observational knowledge about the environment and daily life, the early-implanted group scores were significantly different than those of the late-implanted group (U=609; p<0.01). In the early-implanted group, 16.7% of the children scored "0," and 20% answered all the questions, i.e., achieving a total score [mean=2.62, standard deviation (SD)=1.75, range=0-5]. In the late-implanted group, 54.2% of the children scored "0" and only 8.2% answered all the questions (mean=1.38, SD=1.74, range=0-5).

Table 4. Receptive and expressive language performances of the early- and late-implanted groups

	Age at implantation	Mean	Median	Standard deviation	Minimum	Maximum
Receptive language performances	Early (n=42)	74.24	85	23.737	16	97
	Late (n=48)	51.27	49	25.982	12	97
Expressive language performances	Early (n=42)	76.07	85	22.695	25	97
	Late (n=48)	55.88	50	25.087	12	97

Table 5. Receptive and expressive vocabulary skills of children in the early- and late-implanted groups

	Age at implantation	Mean	Median	Standard deviation	Minimum	Maximum
Receptive vocabulary skills	Early (n=42)	85.93	83.50	15.861	63	132
	Late (n=48)	68.35	63	12.343	56	113
Expressive vocabulary skills	Early (n=42)	87.83	86	15.093	60	125
	Late (n=48)	71.27	70	12.512	56	109

Table 6. Comparison of auditory reasoning performances between the early- and late-implanted groups

Age at implantation	Mean	Median	Standard deviation	Minimum	Maximum
Early (n=42)	17.38	20.5	10.215	0	31
Late (n=48)	8.44	3	10.152	0	30

Table 7. Relationship between the auditory reasoning and language performance

		TELD-3 Receptive Language	TELD-3 Expressive Language	TIFALDI Receptive Vocabulary	TIFALDI Expressive Vocabulary
SIMIBT	Rs	0.868**	0.879**	0.717**	0.688**
Total	N	90	90	90	90

**p<0.01

TELD–3: Test of Early Language Development; TIFALDI: Turkish Expressive and Receptive Language Test; SIMIBT: Selcuk Auditory Reasoning and Processing Skills Test

Table 8. Regression analysis to predict auditory reasoning performances of all participants

Model	R^2	F	B	ß (beta)	T	VIF
TEDIL expressive language subtest			0.273	0.639	9.170	2.300
TIFALDI receptive language subtest	0.819	129.414	0.205	0.307	4.574	2.132
Chronological age			1.338	0.131	2.499	1.301

TELD–3: Test of Early Language Development; TIFALDI: Turkish Expressive and Receptive Language Test.

The "Arithmetical Reasoning" subtest assessed children's ability to use their logic for solving problems or understanding the relationship between numbers and arithmetic problems. There was a statistically significant difference between the early- and late- implanted group in the arithmetic reasoning tasks (U=615.5; p<0.01). In the early-implanted group, 11.9% of the children scored "0," and 26.2% correctly answered all items in this subtest (mean=2.98, SD=1.70, range=0–5). In the late-implanted group, 47.9% of the children scored "0" and 10.4% answered all the questions (mean=1.58, SD=1.85, range=0-5).

The "Verbal Absurdities" subtest assessed what was absurd or meaningless in a statement and why it was so. The early- and late-implanted groups showed a significant difference in this subtest score, and the early-implanted group's performance was significantly different (U=582.5; p<0.01). In the early-implanted group, 47.6% of the children answered all items correctly but 23.8% could not answer any of the questions (mean=3.19, SD=2.14, range=0-5). In the late-implanted group, 14.6% of the children answered all items correctly but 52.1% could not answer any of the questions (mean=1.75, SD=2.05, range=0-5).

The "Analogical Completions" subtest assessed how children completed a sentence after determining the relationship between the first and second statements. The early-implanted group scored significantly different than the late-implanted group (U=537.5; p<0.01). In the early-implanted group, 45.2% of the children completed all items correctly and 14.3% could not answer any item correctly (mean=3.29, SD=1.93, range=0-5). In the late-implanted group, 50% of the children could not answer any items and only 12.5% correctly answered all items in this subtest (mean=1.63, SD=1.96, range=0-5).

The "Causal Reasoning" subtest assessed the children's ability to understand the relationship between events and to comprehend the topic. The early-implanted group scored significantly different than the late-implanted group (U=464.5; p<0.01). In the early-implanted group, 14.3% of the children could not answer any items and 21.4% correctly answered all items (mean=3.50, SD=2.11, range=0–6). In the late-implanted group, 60.4% of the children could not correctly answer any item (mean=1.38, SD=1.96, range=0–6), and only two children correctly answered all items in this subtest.

The "Similarities" subtest assessed the children's ability to comprehend the similarities between two or more objects or ideas and to determine the similarity between more than two objects. The early-implanted group scored significantly different than the late-implanted group (U=618, p<0.01). In the early-implanted group, 40.5% of the children scored "0" and 14.3% achieved the total score (mean=1.86, SD=1.93, range=0–5). In the late-implanted group, 77.1% of the children scored "0" and 4.2% answered all the questions (mean=0.63, SD=1.38, range=0–5).

Relationship between auditory reasoning performances and other variables

As discussed in the previous section, auditory reasoning skill was highly related to language performances and vocabulary skills. There was a strong relationship between SIMIBT, TELD-3, and TIFALDI scores (Table 7).

These results suggest a strong relationship between auditory reasoning, language performance and vocabulary skills. Stepwise regression analysis was applied to predict the auditory reasoning skills using these variables. The stepwise method is similar to the forward method. The difference between the stepwise and forward regression analysis methods is that a new predictor is not added to the equation: "…the regression equation is constantly being reassessed to see whether any redundant predictors can be removed" [21]. We chose stepwise regression to eliminate the variables that have higher correlations. Table 8 indicates a strong relationship between language tests. This relationship makes it further difficult to differentiate the effects of language variables. The chronological age of children with a cochlear implant, expressive language subtest of TELD-3 score, and receptive vocabulary subtest of TIFALDI score were the variables included in the model, and the model could explain 82% of the auditory reasoning performances of the children. The model was as follows: Auditory Reasoning Performance=−32.232+0.273×expressive language subtest of TELD-3 scores+0.205×receptive vocabulary subtest of TIFALDI scores+1.338×chronological age (Table 8). The regression analyses results showed no difference if the duration of cochlear implant use or chronological age entered the analysis. We choose chronological age as the variable for highlighting the development of the auditory reasoning skills of children when they grew older.

DISCUSSION

In the current research, we compared the auditory reasoning performances of children with early and late cochlear implantation aged between 7 and 10 years. Our results indicate that the age at implantation has an impact on auditory reasoning skills. Our findings are congruent with previous findings, which demonstrated that children with cochlear implants, who use listening and spoken language communication as their primary communication approach, have difficulties in auditory reasoning tasks when they have longer auditory deprivation. An important finding in our results was that some children in the early-implanted group could also not perform well in auditory reasoning tasks. This suggests that variables other than age at implantation and language performances influence auditory reasoning skills.

We assessed daily communication skills using FAPCI. We found that daily communication performances of children in the early-implanted group were better than those of the children in the late-implanted group, which was similar to that observed in other studies [22]. Meister et al. [23] asserted that if the duration of auditory deprivation is longer, daily communication skills could be or would be poorer. Additionally, FAPCI scores were highly correlated with language and vocabulary scores. Stacey, Fortnum, Barton, and Summerfield obtained identical results in a larger group of children.

In our study, daily communication scores of children who started using hearing aids earlier were higher than those of children who started using hearing aids later. These results revealed the importance of early diagnosis of hearing loss and attending intervention programs to improve daily communication skills.

As hypothesized, we observed significant correlations between the auditory reasoning and daily communication skills. This relationship could be attributed to the fact that auditory reasoning skills were needed in everyday conversations and necessary for problem-solving.

In our study, language performances, especially expressive language performances of the early-implanted group were better than those of the late-implanted group. Additionally, expressive language performances showed significant and strong relationship with auditory reasoning performances and vocabulary scores.

Vocabulary performances of the early-implanted group were better than those of the late-implanted group. Although there was no significant relationship between the chronological age and vocabulary scores, a strong correlation was observed with the age at cochlear implantation. Similar results revealed that vocabulary performances of cochlear implant users were below the standardized scores established from typically-developing children. When they used the hearing age that indicated the duration of cochlear implant use, the mean scores on the vocabulary test of children with cochlear implants were in the normal range [24-26]. This delay has been observed even in children who received implants at an age younger than 18 months. Furthermore, Connor et al. [27] showed that vocabulary knowledge improved more in early implant users than in late implant users. Our findings were similar to those of the aforementioned study and showed the relationship between vocabulary skills and both the receptive and expressive subtest scores.

As we hypothesized, vocabulary knowledge is also an essential skill for auditory reasoning performances. There is a strong relationship between language, vocabulary, and auditory reasoning performances. This finding suggests that the development of auditory reasoning skills should be encouraged along with the development of vocabulary skills from an early age.

A limited number of auditory reasoning studies have been conducted on children who are deaf or hard of hearing. As observed in the literature, researchers mostly prefer non-verbal reasoning tasks, total communication, and sign language in reasoning studies. In our study, all children communicated through listening and spoken language communication, and the auditory reasoning test was presented in a listening and spoken language condition. As hypothesized, the early-implanted group had significantly higher auditory reasoning scores than the late-implanted group.

Another study compared analogical reasoning skills of children who were deaf or hard of hearing in two age groups (9-10 and 12-13 years old) and communication methods in the family (deaf parents and normal hearing parents) [14]. In both the groups, children who had intensive and regular language intervention from early years performed better in analogical reasoning than those who did not. Our findings showed strong relationships among language scores, vocabulary knowledge, and auditory reasoning scores, which are consistent with the findings of Bandurski and Galkowski [14]. Edwards et al. [28] reported that children who use hearing aids and cochlear implants had lower scores in analogical reasoning tests than their peers with normal hearing. Their regression analysis indicated that when the chronological age and analogical reasoning scores were controlled, language became an essential variable. Thus, they emphasized that extended vocabulary skills and high-level language abilities could be indirectly related to analogical reasoning skills. In our regression analysis, we demonstrated that if we control vocabulary and language scores, we can be predicted auditory reasoning performances of children with cochlear implants. Likewise, Wu et al. [29] reported significant differences between children with hearing loss and those with normal hearing regarding verbal subtests performances on WISC-III. In their study, children who were deaf or hard of hearing and those with normal hearing had similar results in vocabulary, arithmetic, and general knowledge. However, children with normal hearing performed better at similarities and interpretation items than children who were deaf or hard of hearing. Our results indicate similar results with some children in the early implantation group who performed poorly in similarity and causal reasoning subtests.

In future studies, pragmatic language skills of children should be evaluated to identify the effects of different aspects of language. However, very few language tests in Turkish have normalization values and standard scores. Another limitation of the study is that we could not more comprehensively assess cognitive skills of the enrolled children. The correlation between cognitive abilities and auditory reasoning skills of cochlear implant users should be studied.

CONCLUSION

The positive effect of early intervention and benefits of early cochlear implantation are well-known in the literature. However, we need to enhance our rehabilitation programs for obtaining these advantages of early cochlear implantation. As seen through our results, early cochlear implant users still need to improve their higher-cognitive skills, such as reasoning. Higher-cognitive skills are necessary to more creatively solve everyday problems and help to cope with the difficulties of life.

Ethics Committee Approval: Ethics committee approval was received for this study from Hacettepe University Non-Interventional Clinical Research Ethics Board (2015/14:299).

Informed Consent: Informed consent was received for all cases.

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