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Original Article

A Comparison of Phonological Processing and Sentence Comprehension of Normal Hearing Children and Those with Cochlear Implant Experience

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ABSTRACT

Background and Objective: The purpose of the present study is to investigate the phonological processing and sentence comprehension in children with CIs and compare them with normal hearing (NH) children. It is also an attempt to study the relation between phonological processing and sentence comprehension in children with CIs.

Methods: Twenty children with CIs and twenty NH children between the ages 4 to 6 years were evaluated with the Non-Word Repetition (NWR) task ; Persian Syntax Comprehension Test (PSCT); Persian version of Test of Language Development, Primary, 3rd (TOLD-P: 3); nonverbal part of the Wechsler Pre-school and Primary Scale of Intelligence (WPPSI) test; and Vineland adaptive-behavior scale.

Results: These results implied that children with CIs may experience difficulties in phonological processing and sentence comprehension. In children with CIs, with increasing their experience in processing of sound, sentence comprehension skills improved.

Conclusion: The findings of the present study demonstrated that there is a relationship between the NWR and sentence comprehension. Therefore, paying more attention to the intervention of phonological processing may help children with CIs in sentence comprehension.

Keywords: Non-Word repetition, Sentence comprehension, Phonological processing, Cochlear implant, Deaf children

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Introduction

Severe and profound hearing impairment in children can affect speech perception (Calmels, Saliba et al., 2004). Cochlear implant (CI) is one of the interventions that can enhance speech perception by reconstructing the auditory sense (Calmels & Saliba et al. , 2004; Jiménez, Pino et al., 2009; Lee & Yim et al. 2012, Chen & Wong et al., 2014). However, speech perception has different levels among children with CIs and is affected by elements such as the age of hearing impairment diagnosis, residual hearing before implantation, age at implantation, duration of CI use, rehabilitation, etc. , which can influence these children and produce various results in their language skills including speech perception (Dawson et al., 2002; Pisoni & Cleary 2003; Lina-Granade et al. 2010; Löfkvist et al. 2014). Moreover, limitations regarding the number of intra-cochlear electrodes (12-22) in CI devices result in different auditory experiences in children with CIs in comparison to normal hearing (NH) children, which causes speech perception difficulties (Chen, Wong et al. 2014).

Some research has shown that learning speech perception depends on the mental faculties in children; however, many studies have pointed out that it also requires reception of inputs (Corbetta et al., 1990; Huttenlocher et al., 2002; Pisoni & Cleary, 2003). Thus, it is not yet known which of the syntactic skills are influenced by linguistic input during language development, but it is possible that the various syntactic

aspects are specifically sensitive to the inputs during language development (Huttenlocher et al. 2002). Thus, it could be concluded that receiving inputs is a need for speech perception.

In order for a concept to be conveyed, a number of words are arranged to form a sentence based on syntactic rules (Fallon et al., 2006). Sentence processing is carried out at different levels such as phonemic, semantic, and syntactic levels (Pisoni & Cleary, 2003). In phonological processing, the phonemes must be mentally represented and manipulated (Wingfield & Tun, 2001; Lee et al., 2012). Since phonemic processing involves phonemic awareness, phonological memory, and lexical access, and since Non-Word Repetition (NWR) task checks the phonological memory, it could be said that NWR task measures the phonological processing (Lee et al., 2012; Soleymani et al., 2014).

In NWR task, the child has to represent a set of phonemes, store them in the memory, and restate them in the same order (Soleymani et al., 2014). Studies show that sentence comprehension similar to NWR requires phonemic representation (Wingfield & Tun , 2001). Therefore, the present study assumes that phonologic processing is a predictor of sentence comprehension in children. It is also assumed that the lower the age of implementation and longer the duration of CI use, the closer the phonological processing and sentence comprehension of children with CIs are to NH children of the same age. Thus, the present study is an attempt to compare children with CIs and NH children with respect to NWR and sentence comprehension. It also aims to study the following relations: NWR and sentence comprehension, NWR and age at implantation, sentence comprehension and age at implantation, NWR and duration of CI use, and sentence comprehension and duration of CI use.

Material and Methods

Participants

The current study was performed on Persian-speaking NH Children and Children with CIs between the ages 48 to 72 months. The NH children were selected from some of kindergartens and the Children with CIs were selected from three hospitals in Tehran (Iran). All participants were reported being right-handed and they showed no evidence of anatomical abnormalities, neurological disorders (except for hearing loss in the Children with CIs), metabolic illness, mobility problems, vision problem that could not be corrected with glasses or contact lenses, genetic syndromes, motor-speech disorder, or delay in psychomotor developmental indices; according to the parental reports and the examiner's observations. Intellectual abilities of the participants were evaluated with the nonverbal section of Persian version of Wechsler Pre-school and Primary Scale of Intelligence (WPPSI) (Razavieh & Shahim 1990), which was conducted by a psychologist. The scores of all the participants were above 85 in the WPPSI test (NH children: M = 94.80, SD = 6.40; Children with CIs: M = 90.25, SD = 3.19). Socio-adaptive abilities of the participants were evaluated with Vineland adaptive-behavior scale (McKinlay , 2011) and scores of the participants were appropriate for their age.

Children with CIs

The group consisted of 20 children with CIs (10 girls and 10 boys) between the ages 4 to 6 years (M = 60.60 months, SD = 9.82). The demographical characteristics of the children with CIs are present in Table 1. The experience of using implant did not exceed 3 years in any of the children with CIs and the means length of the utterance (MLU) was 3 words. The parents of these children had normal hearing. The method of communication with all the CI participants was oral. All the participants had pre-lingual and bilateral HI and only one of their ears (right ear) had gone through surgery. All participants used advanced combined encoder Nucleus implant brand that activated 19-22 electrodes in their arrays. For ensuring about the proper functioning of CI devices and speech perception in these children, an audiologic assessment was carried out. It was checked whether the cochlear implant device was on to ensure that the children with CIs heard the test stimuli. Then the therapist asked every child to perform a few simple verbal tasks.

NH children

This group consisted of 20 children (11 girls and 9 boys) between the ages 4 to 6 years (M = 59.35 months, SD = 8.90). According to the parents' reports, these children had normal phonemic and production skills. Their language skills were appropriate with their age, as assessed with Persian version of Test of Language Development, Primary, 3rd (TOLD-P:3) (Hasanzadeh & Minaiee, 2001).

Procedure

The study was approved by the Ethical Committee of Iran University of Medical Sciences (Code number: IR.IUMS.REC 1395.9311360002). All parents filled an 'informed consent', and the children's 'verbal assent' to participate in the experiment was obtained. Parents were asked to complete questionnaires (Vineland adaptive-behavior scale and a questionnaire about the history of development of the child). Participants were selected according to parental responses. All children sat on a chair and answered the examiner's questions verbally or otherwise and provided their answers by pointing to pictures. It should be noted that before the tests, the therapist gave a few examples to the child to ensure he/she had understood how to answer the questions.

Sentence Comprehension Task

Sentence comprehension was measured by the PSCT which was normed on 436 Persian- speaking children between the ages 4 to 6 years. It measures 24 structures of syntax and includes 96 items (Mohamadi, Alavije et al. 2015). The score range of PSCT is 0-24. The examiner reads the sentences and the participant must select one out of 4 pictures; the one which is designed for the appropriate construction.

NWR task

Repetition of non-words was measured by Persian version of NWR task (Afshar, Qorbani et al. 2013). The NWR task was performed on 4 to 6 year-old Persian-speaking children. This task consists of 25 non-words that have similar constructions with Persian words. The score range of this task is 0-53. The content validity of the task was 0.99 and Pearson correlation and Cronbach's alpha respectively showed 0.979 and 0.972 of reliability. In NWR task, the examiner reads the non-words and the participants should repeat them immediately. Each participant was given 2 seconds to repeat each non-word.

Persian Version of TOLD-P: 3

This test was carried out by Hassanzadeh and Minaee (2000) in 'Research Institute for Exceptional Children' on 1235 Persian-speaking children (609 girls and 626 boys) between the ages 4.0 to 8.11 years. The test entailed expressive and comprehensive language. The reliability of the test was obtained by Cronbach's alpha, which was 0.74-0.94 for the different subtests. The construct validity was obtained by age differentiation; the correlation between the subtest and age was 0.38-0.61. The results coming from the psychometric showed the test was valid and reliable. Therefore, the test could be used as an instrument for identifying children who have weaker language skills than their peers and for identifying their strengths and weaknesses in these skills. In each subtest, the correct answers were given a score of 1 and the wrong answers a score of 0. The subtest was stopped after 5 consecutive failures. The production section encompassed oral questions which should be answered verbally. The comprehension section involved showing pictures to the child and the child was to select the right picture according to what was said by the therapist.

Statistical Analysis

The results were analyzed by SPSS version 16. The Kolmogorov-Smirnov (KS) test was performed for studying the normal distribution of the data. Children's level of NWR and sentence comprehension were described by a descriptive analysis (mean, standard deviation, and range). In addition, an independent t-test was used to investigate the differences between the scores described in the two groups. Finally, two-sided Pearson correlation coefficient was used to detect the relation between NWR and sentence comprehension and was also used for finding relation between all tasks with the age at implantation and the duration of CI use. For all analyses, p-value was considered to be less than or equal 0.05.

Results

Comparison Between Two Groups of Children

The demographic features of children with CIs and NH children evaluated in this study are described in table 1. The average scores of NH children were higher than children with CIs in NWR task, TOLD-P: 3 and PSCT. Table 2 summarizes the results of the t-test comparisons. The t-test revealed a significant difference between the two groups in NWR task (t38 = 10.943, P = 0.00), TOLD-P: 3 (t25.26 = 9.103, P= 0.00) and PSCT (t38 = 10.293, P = 0.00). These results are depicted in Fig.1.

Correlation Between Tasks

Table 3 presents the results of two-sided Pearson correlation in NWR and sentence comprehension scores in children with CIs and NH children. The CI children's NWR scores were found to correlated with sentence comprehension scores (r = 0.47, P = 0.03), which is shown in Fig. 2. But the NWR score in NH children (r = 0.17, P=0.45) did not correlate with sentence comprehension score (P > 0.05).

Correlation of NWR and Sentence Comprehension Scores with Age at Implantation and Duration of CI Use

To find the relation between children's responses on NWR, sentence comprehension and their age at implantation and duration of CI use, we carried out correlation analysis. The result showed that the children's age at implantation was negatively correlated with NWR scores (r = -0.23, P= 0.31) and sentence comprehension scores (r = -0.39, P= 0.08). However, these were not statistically significant (P> 0.05). These results are depicted in Fig.3.

In contrast, the duration of CI use was positively correlated with NWR (r = 0.16, P= 0.48) and sentence comprehension (r = 0.45, P= 0.04). However, only the relation between duration of CI use and sentence comprehension was statistically significant (P < 0.05) (see Table 4). That is, children whose duration of CI use was further gained higher scores in sentence comprehension than children whose duration of CI use was less. These results are depicted in Fig.3.

Table 1. Demographical characteristic of Children with CIs.

Demographic Characteristics	Children with CIs n = 20	
	Mean	SD
Age (months)	60.60	9.82
Age at implantation (months)	26.40	11.78
Duration of CI use (months)	34.25	10.53
Age of diagnosis hearing impairment (months)	6.35	4.29

Table 2. Descriptive analysis of domains in NH children (n = 20) and children with CIs (n = 20).

	Children with CIs			NH children			t-value	P-value
	Mean	SD	Range	Mean	SD	Range		
NWR	21.80	10.79	5-44	49.75	3.74	39-54	10.943	0.00**
TOLD-P: 3	61.25	23.68	0-94	113.40	9.75	97-130	9.103	0.00**
sentence comprehension	0.80	1.36	0-5	9.90	3.71	4-17	10.293	0.00**

Table 3. Correlation between Sentence comprehension and NWR in NH children and Children with CIs.

	NWR	
	Children with CIs	NH children
Sentence comprehension	0.47*	0.17
	* P < 0.05.	
	** P < 0.01.	

Table 4. Correlations between NWR, and sentence comprehension with age at implantation and with duration of CI use (n = 20).

	Age at implantation	Duration of CI use
NWR	-0.23	0.16
Sentence comprehension	-0.39	0.45*

* $P < 0.05$.

** $P < 0.01$.

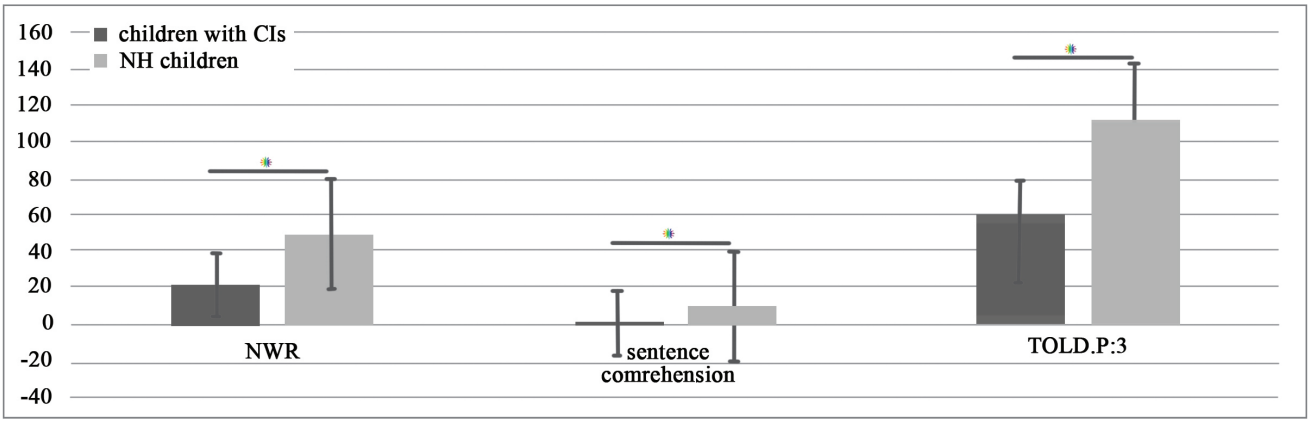

Fig. 1. Error bars of NWR, TOLD-P: 3 and sentence comprehension in children with CIs and NH children. Error bars also indicate standard errors

Discussion

This paper studied the difference in NWR and sentence comprehension performances in Persian- speaking NH children and children with CIs. It also studied the relation between NWR and sentence comprehension as well as the relations between NWR and age at implantation, sentence comprehension and age at implantation, NWR and duration of CI use, and sentence comprehension and duration of CI use.

The results showed that children with CIs had lower performance in comparison to NH children of the same age in the NWR task. The findings of this study are in line with many of the studies conducted on NWR (Carter et al., 2002; Dillon et al. 2004; Ibertsson et al., 2008; Casserly & Pisoni 2013). Children with CIs in this study had been deprived of phonemic inputs for a maximum of 3 years (M = 26.40, SD = 11.78), whereas the NH children of the same age had received phonemic inputs since birth. Previous studies indicate that phonological processing is poor in children with CIs who have hearing impairment during language development and do not received phonemic input (Corbetta et al., 1990; Lee et al., 2012). As stated earlier, NWR task measures phonemic processing (Lee et al. 2012; Soleymani et al. 2014). Therefore, it is probable that phonemic input deprivation in these children during language acquisition resulted in poor phonological processing in comparison to NH children of the same age.

Additionally, results indicated that children with CIs did not perform as well as NH children of the same age in sentence comprehension, which is in line with studies carried out in this respect (Calmels et al. 2004, Löfkvist et al. 2014; Willis et al., 2014). Children with CIs have difficulties in language skills, including sentence comprehension due to deprivation of phonemic input. Moreover, their auditory sense is different from NH children after CI surgery and the reconstruction of auditory sense for the limited number of electrodes in the CI devices, which can be yet another cause of their poor sentence comprehension (Chen et al. 2014). The number of active electrodes of each row in this study was 19-22, and only on the ear that had CI; the other ear with profound hearing impairment did not have hearing aids.

The study indicated that there is a relation between NWR and sentence comprehension in children with CIs. Previous studies indicate that perceptual process-

ing skills are developed during pre-school ages in NH children (Nittrouer et al., 2012). The basis of these skills is phonological structure, whose development begins in the embryonic period (Henry et al., 2005). In pre-lingual hearing impairment, the child is deprived of auditory input, including phonological structures, which can exert influence on the processing abilities (Corriveau et al., 2010). As studies show, phonological processing plays a major role in the comprehension of sentence (Dawson et al. 2002). In NWR task, the phonemes must be heard, stored in the memory after they are represented, and then reproduced. The same goes for sentence comprehension (Wingfield & Tun, 2001; Lee et al., 2012; Soleymani et al., 2014). Hence, it is possible that phonological processing affects sentence comprehension in children with CIs. However, such influence was not observed in NH children in this study. In this experiment, NH children had 4 to 6 years' experience of auditory input (M= 59.80 months) whereas children with CIs had a shorter experience (M = 34.25 months). As stated before, the different aspects of syntax have a different sensitivity to the input in the different phases of development (Corbetta et al., 1990, Huttenlocher et al., 2002, Pisoni & Cleary, 2003); therefore, it is probable that the roles played by phonological processing and phonemic input reception in sentence comprehension are greater at lower ages than the ages of 4 to 6. Another cause for the relation to being insignificant in NH children could be the small sample size (n = 20).

There was a negative correlation between NWR and age at implantation and also between sentence comprehension and age at implantation. Much research has been conducted on the relation between sentence comprehension and age at implantation (Willstedt-Svensson et al. 2004; Percy-Smith et al., 2013, Mandal et al., 2016). All these studies emphasized that higher scores were marked in sentence comprehension in children who had surgery before the age of one. Studies on the relation between age at implantation and NWR shows that although children with CIs have difficulties in NWR, the duration of hearing impairment is related to their performance in NWR task, because better perception of sounds in children with CIs leads to better performance in NWR task (Soleymani et al., 2014). It follows that the younger the age at implantation, the more the language skill development takes place. There was also a positive correlation between NWR and the duration of CI use and also between sentence comprehension and the duration of CI use; however, it was only significant for the relation between sentence comprehension and the duration of CI use. Calmes et al. (Calmels et al. , 2004) studied the relation between the duration of CI use and comprehension in children with CIs, whose results on sentence comprehension were confirmed by the current study. Soleymani et al. (Soleymani et al., 2014) emphasized the existence of a relation between NWR and duration of CI use; they contended that probably the greater the duration of CI use, the greater is the sentence comprehension. In this study, the mean age at implant was 26.40 months and the mean age of CI use was 34.52 months. One reason for the insignificant relation between NWR and age at implantation, the relation between sentence comprehension and age at implantation, and the relation between NWR and the duration of CI use in this study could be the small sample size (n = 20). Also, the findings show that in addition to the listed elements affecting speech perception, other elements such as the age of diagnosis of hearing impairment, residual hearing before implantation, using hearing aids before the CI surgery, hearing ability of the parents, etc. also affect speech and language development as well as age at implantation (Dawson et al., 2002, Pisoni & Cleary, 2003; Lina-Granade et al., 2010, Löfkvist; Almkvist et al., 2014). Another cause for the insignificant relation between these relations could have arisen from the difference in hearing for the children with CIs. In this study, mostly one ear — mostly the right one — had CI (M = 0.85), and the other ear did not have hearing aids, but in other studies showing a significant difference, both ears had CI. Moreover, the number active electrodes in this study was 19-22 in each row, while other studies reported 22 electrodes (Willstedt-Svensson et al. 2004; Percy-Smith et al., 2013).

Two decades almost have passed since the first CI surgery in Iran; therefore, children with pre- lingual

deafness or profound hearing impairment have benefited from CI at different ages. Thus, children of the same age are not homogeneous with respect to age at implantation and duration of CI use (Soleymani et al., 2014), which could result in a greater variety of speech and language skills in children with CIs (Dawson et al., 2002; Pisoni & Cleary, 2003; Lina-Granade et al., 2010). In addition to comparing phonological processing and sentence comprehension in two groups of children, the present study aimed at helping to develop a better treatment program for enhancing speech and language skills for children with CIs by finding the relation between NWR and sentence comprehension as well as the relations between NWR and age at implantation, sentence comprehension and age at implantation, NWR and duration of CI use, and sentence comprehension and duration of CI use. Although there are other factors besides age at implantation and duration of CI use, the significance of these two factors cannot be ignored.

Limitation

There were some limitations in our study approach, one of which was the small sample size, therefore; and the results are potentially unreliable and need to be interpreted cautiously. Another limitation came from the lack of a standard NWR test. It is essential that future studies make an attempt to develop a norm-referenced NWR test. It is also crucial to study the other components of phonological processing such as phonological awareness and lexical access as well as the relations of all the components with the various syntactic structures.

Conclusion

Children with CIs have a poor performance in skills such as phonological processing and sentence comprehension in comparison to NH children of the same age. However, a longer experience of using CI devises might result in better sentence comprehension due to more reception of linguistic input. Thus, it is recommended that children suffering from severe and profound hearing impairments in the pre-lingual stage undergo CI surgery before the age of one. Also, given the relation between phonological processing and sentence comprehension in this study, it is recommended that speech and language pathologists pay more attention to the intervention of phonological processing skills in order to improve sentence comprehension in children with CIs.

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Conflict of Interest

Authors declared no conflict of interest.

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مقالهٔ پژوهشی

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چکیده

زمینه و هدف: آسیب شنوایی شدید و عمیق درک جمله را تحت‌تأثیر قرار می‌دهد. هدف مطالعهٔ حاضر بررسی پردازش واجی و درک جمله و بررسی ارتباط بین این دو متغیر در کودکان دارای کاشت حلزون و کودکان شنوای طبیعی است.

روش کار: ۲۰ کودک کاشت حلزون شده و ۲۰ کودک شنوای ۴ تا ۶ ساله به شیوهٔ تصادفی ساده برای این مطالعه انتخاب شدند. کودکان کاشت حلزون شده از سه بیمارستان و کودکان شنوا از چندین مهدکودک شهر تهران انتخاب شدند. آزمایهٔ تکرار ناکلمه، آزمون درک نحو زبان فارسی، نسخهٔ فارسی آزمون رشد زبان و بخش غیرکلامی آزمون هوش وکسلر روی آنها اجرا شد.

یافته‌ها: نتایج نشان داد در آزمایهٔ تکرار ناکلمه و درک جمله، تفاوت معناداری بین کودکان کاشت حلزون شده و کودکان شنوا وجود داشت (P=۰/۰۰۰). میانگین امتیاز هر دو متغیر در کودکان شنوا بیشتر بود. در کودکان دارای کاشت حلزون نمرهٔ آزمایهٔ تکرار ناکلمه به‌طور معناداری با نمرهٔ درک نحو همبستگی داشت، در حالی که در کودکان شنوا بین تکرار ناکلمه و درک جمله همبستگی معناداری به دست نیامد (P=۰/۰۵).

نتیجه‌گیری: کودکان کاشت حلزون شده در مقایسه با کودکان شنوای همسن خود، در پردازش واجی و درک جمله عملکرد ضعیف‌تری دارند. درک جمله در کودکان کاشت حلزون شده با توانایی پردازش‌های واجی در ارتباط است.

واژه‌های کلیدی: مقایسهٔ توانایی زبانی، پردازش واجی، درک جمله، کودکان دارای کاشت حلزون، کودکان شنوای طبیعی