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Relationship between working memory and comprehension and expression of grammar in Farsi-speaking children with cochlear implants

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ABSTRACT

Objectives: Grammar is one of the most fundamental components of language and working memory (WM) is one of the most important cognitive features. These two skills play a vital role in learning, literacy and communication. Children with cochlear implants (CIs) experience delays in both of these skills. The aim of this study was to investigate the relationship between these two skills in children with CIs.

Subjects and methods: The sample consisted of 20 Farsi-speaking children with CIs. WM was estimated by forward and backward auditory digit spans (FBS and BDS) from the Persian (Farsi) version of the Wechsler Intelligence Scale for Children, 4th edition. The comprehension of grammar by participants was evaluated using the Persian Syntax Comprehension Test. Grammar expression was assessed using the Photographic Expressive Persian Grammar Test. Pearson's correlation and simple linear regression were used for data analysis.

Results: The results of linear regression and correlation showed a strong correlation between comprehension of grammar and FDS ($r = 0.61$; $p = 0.004$) was obtained, between BDS and comprehension of grammar ($r = 0.161$; $p = 0.080$). FDS and expression of grammar ($r = 0.163$; $p = 0.222$) showed a positive but insignificant correlation.

Conclusion: The results indicate that WM decisively effects grammar. Enhancement of the phonological loop can improve grammar, especially comprehension of grammar. The effect of the central executive in grammar requires further research.

1. Introduction

The Baddeley model (Baddeley, 2000) [1] states that working memory (WM) is a multi-component system and each component is responsible for a different function. This model contains four components; the phonological loop (PL), visuospatial sketchpad, central executive (CE) and episodic buffer. The growth of the PL and CE have a direct relationship with the development of vocabulary, comprehension, reading and speech production [1,2]. The forward digit span (FDS) is used for assessment of the PL and the backward digit span (BDS) for the executive system [3,4]. Numeric stimuli are a reliable tool for measuring WM [5].

CI, grammar, WM, and short term memory were the keywords that we searched in Google Scholar, PubMed, Web of Science, Scopus and publisher databases (Springer, Science Direct) to find related studies. Several studies have investigated the relationship between language and WM in normal individuals and individuals experiencing language impairment [2,6–8]. Neuropsychological evidence suggests that patients with PL impairment are incapable of learning a new language [9–12]. Service (1992) studied learning of English as a second language by young Finnish children and found that those with good WM acquired syntax and vocabulary better than the others [13]. The ability to repeat a non-word or digit or word span as a task for assessment of the PL has been linked to vocabulary and grammatical skills in normally developing children [14–16]. Gathercole found that learning of new vocabulary by normal children, especially in the early stages of language acquisition, is dependent on the PL of WM [17].

Most children who are born with severe to profound hearing loss have significant delays when compared with their normal growth counterparts for language development and cognitive skills such as memory, attention and learning [18–20]. Language delays in children who receive cochlear implants (CIs) has been confirmed by several studies [21–25]. A delay in access to language, especially in grammar, has negative consequences that CI children cannot easily overcome [26]. Tomblin reported a significant difference between CI users and their normal hearing (NH) peers in terms of sentence comprehension

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and correct use of grammar [27]. They produced more simple syntactic structures than their NH peers and they had difficulty perceiving and expressing complex syntactic structures [27–29].

Children with CIs have various problems understanding and expressing grammatical morphology [26] in different languages, including French and German [30,31]. Studies have shown that the acquisition of language skills requires more time in children with CI compared to NH children and complex grammatical skills are acquired much later than other linguistic aspects [32]. Although the purpose of a CI for hearing-impaired children is to provide an auditory experience to achieve a desirable language level [33,34], the study of cognitive skills makes it possible to discover the relationship between these skills and the language development by CI children [35] and to consider it when planning therapy.

In addition to language problems in children with CIs, studies have addressed the cognitive problems of these children, including attention, memory and learning [14,36]. To indicate the importance of WM, Gathercole, and Alloway found WM impairment of up to 10% below normal levels causes 80% of reading and math problems in normally developing children [37]. Some studies on WM in CI children have shown that these children show poor performance in this skill. None of these studies showed a prevalence of WM impairment in these children, but they all confirmed that children with CI experience WM delay compared to NH children [38–40]. Because of disturbed phonological representations of verbal input and a history of reduced hearing, children with CIs are at high risk for WM impairment [39,41–44]. Nittrouer et al. [42] tested NH and CI children in phonological awareness/processing, serial recall of words, vocabulary, reading and grammar. They concluded that non-word repetition tasks could be used to evaluate language acquisition for school-age children with CIs. Dawson et al. [44] demonstrated that children with CI performed more poorly in the short-term and in WM relative to the control group. Soleymani et al. [43] investigated WM in Farsi-speaking children with CI and NH. They found that children with CI also show disturbances in encoding, practicing and repeating phonological units resulting from WM impairment. Dawson et al. [44] stated that some WM subsystems, such as serial recall and FDS, have direct links to word recognition and vocabulary respective.

All of this points to the fact that many studies have been conducted on either grammar [28,29] or WM of children with CI [43,45]. All of these studies have shown that children with CI experience delays in these skills. To the best of our knowledge, there has been no study on the relationship between grammar and WM in children with CI. Related studies in this regard have examined the relationship between WM and language as a unit concept [42,44,46–48] or speech [41,49,50] in children with CI, but did not focus on grammar. It remains to be determined whether or not grammar and WM in children with CIs. If such a relationship exists, it must be determine which memory component (PL, CE) is associated with the comprehension and expression of grammar.

Studies have investigated the interface between WM and language in normal children [11,51,52] and often have confirmed the positive relationship between these two skills, so the existence of this connection is evident. Studies such as that by Ibertsson [53] did not consider NH children as a control group. Despite the many studies that have surveyed the correlation between WM and a component of language such as vocabulary [54–56], its relation to grammar is not clear.

2. Methods

2.1. Participants

The present study appraised the WM and grammar skills of 20 children (8 males and 12 females) with profound pre-lingual deafness that received CIs at under two years of age. Because this was a correlation study, there was no control group [57]. The inclusion criteria were to be 70–90 months of age, exhibit congenital hearing loss, received a CI below 5 years of age, be a native speaker of Farsi, have received a CI at least two years previously, the hearing loss should not been caused by a syndrome or neuromuscular disorder, unilateral CI on right ear, right-handed and 24-channel nucleus prosthesis. They were almost at the same level as hearing thresholds; Speech recognition thresholds (SRT) prior to implantation (Rang = 74–79 dB HL) and at test (Rang = 63–66 dB HL).

Table 1
Demographic details of samples.

Measures	Min	Max	Mean (SD)
age at implantation	6 (months)	52 (months)	37 (11.78) (months)
age at testing	70 (months)	90 (months)	78.95 (6.19) (months)
hearing age	24 (months)	72 (months)	42 (13.59) (months)
Speech recognition thresholds (SRT) pre implantation	74 dB	79 dB	75.7 (1.47) dB
Speech recognition thresholds (SRT) post implantation	63 dB	66 dB	64.02 (0.97) dB
Language score	51	91	67 (17.41)

All samples had passed pre-primary school then familiar with the numbers. These children use the total communication method. In terms of language abilities, CI children scored severely weak to moderately (mean = 67, SD = 17.41, Min = 51, Max = 91) according to Test of Language Development-Primary: third edition (TOLD-P: 3) [58].

Ethical approval for the study was obtained from the ethics committee of Tehran University of Medical Sciences in Iran (IR.TUMS.REC.1394.1971). The purpose of the study was explained to parents. All parents signed informed consent forms and filled out case history forms about their children.

The demographic details of the subjects and descriptive data are presented in Table 1.

2.2. Materials

WM was estimated using FDS and BDS from the Farsi version of the Wechsler Intelligence Scale for Children, 4 t h edition (WISC-IV) [59]. The grammar comprehension of the participants was evaluated using the Persian Syntax Comprehension Test [60]. Grammar expression was assessed using the Photographic Expressive Persian Grammar Test [61].

2.2.1. Working memory test

The WM was evaluated using the FDS and BDS subtests of the Wechsler test. The digit spans were presented by means of a live voice at a rate of one item per second. Digit span tasks are simple tasks generally used to evaluate WM skill. The FDS tasks asked subjects to repeat a sequence of random digits between 1 and 9 in forward order. The BDS tasks as subjects to repeat the sequences in inverse order. Both tasks begin with a two-digit sequence. If the child responds correctly, the sequence length is increased until the child responds incorrectly to two items of the same sequence length. FDS and BDS scores were used as measures of auditory WM. The digit span is an appropriate tool for assessing the WM of hearing-impaired children and children with CI [25,41,45].

2.2.2. Persian syntax comprehension test

The Persian Syntax Comprehension Test was developed and standardized by Mohamadi et al. for Farsi-speaking children. This test contains 24 syntactic structures involving 96 items and was used to assess grammar comprehension in children. The test has a strong internal consistency and good content validity. The content validity index (CVI) of the syntactic comprehension test was 0.81, the criterion validity of the test was 0.57 and the internal consistency of the test was