THE ROLE OF SHORT-TERM MEMORY IN THE VOCABULARY OF CHILDREN WITH COCHLEAR IMPLANTS

Ioanna Talli, Areti Okalidou, Miltiadis Tsalighopoulos

Abstract

Deaf and hard of hearing children are delayed in acquiring vocabulary and they often receive below average scores on short-term memory (STM) tasks, such as non-word repetition and digit span. It has been shown that weak performance in STM in deaf children with cochlear implants (CI) may have an impact on the vocabulary. This study aims at exploring whether phonological STM skills can predict vocabulary skills of children with CI. Fifteen children with CI (ages 4:6-8:6) were administered with receptive vocabulary, nonword repetition and digit span measures and were compared to two control groups, matched in chronological (CA) and post-implant age (PIA), respectively. Correlations between phonological STM and receptive vocabulary were found for children with CI, while for the age-matched controls correlations were found between receptive vocabulary and digit span. Phonological STM significantly predicted vocabulary, while duration of use of the CI, non-verbal IQ and digit span did not. Phonological STM seems to be the strongest contributing factor in vocabulary learning among children with CI.

Introduction

Besides vocabulary and language limitations (for a review see Luckner & Cooke, 2010), deaf and hard of hearing children also demonstrate deficits in cognitive skills, for example short-term memory (Harris & Moreno, 2004). Although hearing-impaired children use memory strategies that are similar to their normally hearing (NH) peers, such as covert verbal rehearsal strategies (Campbell & Wright, 1990), they often receive below average scores on short-term memory (STM) tasks, such as non-word repetition (phonological STM) and digit span (verbal STM) (e.g. Pisoni, Kronenberger, Roman, & Geers, 2011). This weak performance on STM tasks could be due to degraded auditory input, resulting in defective or incomplete phonological representations in STM (Pisoni et al., 2011). Furthermore, individual differences in capacity and effectiveness of STM processes might explain the variability of speech and language outcomes in hearing-impaired children and children with CI.

Non-word repetition assesses rapid phonological processing (phonological STM), a fundamental skill underlying spoken language use. In this task the child is asked to listen to a novel nonsense word and to repeat it back aloud. *Digit span* tests on the other hand are commonly used as capacity measures of immediate auditory sequential memory (verbal STM). The child is asked to repeat digits in the same order (or reverse order for backward digit span) as they were presented. Digit span tests assess verbal STM, similar to the 'phonological loop' component of working memory in non-word repetition tests (Baddeley, 2003). However, repetition of non-words relies more on the

temporary storage of phonological representations in STM than on items such as words or digits because of the reduced availability of long-term lexical knowledge to support the unfamiliar phonological forms (Archibald & Gathercole, 2007).

Verbal STM skills are found to be poorer in children with CI (Harris, Kronenberger, Gao, Hoen, Miyamoto & Pisoni, 2013; Pisoni et al., 2011). Apart from digit span, non-word repetition abilities have also been found to be poorer in this population, compared to NH peers (e.g. Casserly & Pisoni, 2013).

The relationship between STM and vocabulary has been studied in children with CI. Vocabulary difficulties in this population have been attributed to low phonological representations and/or difficulties with phonological working memory (Houston, Carter, Pisoni, Kirk & Ying, 2005). Casserly and Pisoni (2013) studied the linguistic and non-word repetition abilities of 52 children with CIs aged 8 to 10 years (who all had at least a 3-year CI use) and how these linguistic and non-word repetition abilities developed after 8 additional years of CI use. The researchers found that measures of non-word repetition obtained in childhood correlated significantly with speech and language abilities in adolescence, 8 years later, including expressive and receptive language, reading and vocabulary knowledge, and speech perception accuracy in both quiet and adverse listening conditions. They concluded that non-word repetition skills could potentially serve as a strong early behavioral marker of children with CI who are at risk of poor language outcomes.

However, the above studies concern English, which is a language with an irregular orthography. The results in two languages with a regular orthography differ: while in Italian phonological STM capacity of children with CI seems to be as robust as that of same-age NH children (Guasti et al., 2012), in French, children with CI show less robust phonological STM abilities (Bouton et al., 2011; Willems & Leybaert, 2009). There are not many studies concerning regular orthographies, such as Greek. To our knowledge, there is no study with Greek children with CI assessing in addition to their lexical abilities their STM abilities as well, and only a few studies conducted in transparent orthographies (e.g. Guasti et al., 2012).

The present study aims at contributing to a better understanding of STM skills and its role in vocabulary development in Greek-speaking children with CI. The research questions of this study are: (1) What is the relationship between (phonological and verbal) STM and vocabulary skills in children with CI and in NH children? (2) Do phonological or verbal STM skills predict vocabulary skills in children with CI and in NH children?

To address these questions receptive vocabulary, phonological and verbal STM skills of children with CI were assessed using both non-word repetition and digit span tasks and they were compared with two control groups with NH.

Method

Participants

Fifteen children (eight males) between 4:7 years and 8:6 years of age, with bilateral severe to profound hearing impairment who had received CI, with normal nonverbal IQ (not below the 25th percentile, as assessed with Raven's

Coloured Progressive Matrices, based on French normative data from Raven, 1947; 1981) and no additional neurological or developmental disorder, took part in this study. The mean age at testing for the children with CI was 6:8 years (SD = 15 months) and their mean age at implantation was 2:7 years (SD = 10 months) (see Table 1). They were all implanted between the age of 1:6 year to 3:9 years. All children received a unilateral implantation on the right ear; they were all prelingually deaf and monolingual Greek-speaking children. Eleven used oral communication and four used both oral and signed communication. Three of them attended a special school for the Deaf (they used both oral and Greek sign language), while the rest were attending mainstream classes with hearing children. They all received or were receiving speech therapy. All children were administered with the Test of Phonetic and Phonological Development (PAL, 1995).

Table 1. *Chronological age at testing, age at implantation and length of cochlear implant use for pediatric cochlear implant users. Ages are given in months.*

Demographic variable	Mean (SD)	Range
Age at testing	79.80 (14.80)	55-102
Age at implantation	31.33 (10.25)	16-45
Length of CI use	48.60 (14.19)	28-80

There were two control groups of children with NH, matched with children with CI. One group was of the same chronological age, sex and nonverbal IQ (CA; n = 15, mean age: 6:8 years, SD = 14 months) and one younger group was matched with years of cochlear implant use (Post-implant age, PIA; n = 15, mean age: 4:1 years, SD = 14 months) and also by sex and non-verbal IQ. All the NH children met the following criteria: (a) they were monolingual speakers of Greek, and (b) they had no history of auditory and language disorders. All families of children in this study were informed and provided a signed written consent before the participation of their child. The children with NH were recruited from the region of Thessaloniki and were either attending public primary schools or public /private kindergartens. There were three children under 3 years of age, who were not enrolled in any school.

Materials and Procedure

Receptive vocabulary. Vocabulary knowledge was assessed with the Greek protocol of Receptive One-Word Picture Vocabulary Test (Martin & Brownell, 2000; Greek adaptation: Okalidou, Syrika, Beckman & Edwards, 2011, under standardization), a test of receptive vocabulary with norms for ages from 2 to 6:6 years. This test assesses children's ability to identify which of four pictures best represents the meaning of each single word spoken by the examiner.

Digit span. Digit Span subtest of Athina Test (Paraskevopoulos, Kalatzi - Azizi, & Giannitsas, 1999) was administered to obtain measures of verbal STM. This test required the child to repeat 16 lists of digits of increased length

(from 3 to 8 digits) that were orally presented by the examiner at a rate of approximately one digit per second. A ceiling was reached when the child made errors in two consecutive lists, in two trials. The accuracy score was the percentage of the total score of the marking used in Athina test.
Non-word repetition. Phonological STM was assessed through a non-word repetition test adapted in Greek from the French battery test EVALEC (Sprenger-Charolles, Colé, Béchennec, & Kipffer-Piquard, 2005; Greek adaption: Talli, 2010). This test included the repetition of 24 three- to six-syllable non-words (6 non-words for each length, of which 3 included only CV syllables, while the other 3 included a CVC syllable) presented orally by the examiner in increasing order of length. The accuracy score was the percentage of the number of syllables correctly repeated*.*

Results

Descriptive statistics are shown in Table 2.

Table 2. *Means and standard deviations of the three groups' performance on non-verbal IQ (Raven), receptive vocabulary (ROWPVT), digit span and non-word repetition*

		CI[a]	**CA**[b]	**PIA**[c]
Non-verbal IQ (Raven): Percentile[d]				
	Mean	65.33	73.00	69.66
	SD	(22.55)	(20.42)	(15.52)
Receptive vocabulary (ROWPVT): Raw scores percentage				
	Mean	22.55	49.14	32.28
	SD	(10.10)	(8.75)	(11.83)
Digit span:				
Raw score percentage	*Mean*	21.25	48.96	21.25
	SD	(14.67)	(26.98)	(18.38)
Non-word repetition:				
accuracy %	*Mean*	39.25	80.37	64.50
	SD	(16.06)	(10.66)	(17.74)

[a] CI = Children with cochlear implant, [b] CA = chronological age control group, [c] PIA = post-implant age control group.
[d] The percentiles are standardized scores from French norms (Raven, 1947;1981)

Correlation analyses assessed the relationship among receptive vocabulary, non-word repetition and digit span skills. Spearman's rank order correlation coefficient (i.e., Spearman's rho) was performed with the receptive

vocabulary, non-word repetition, digit span and rapid naming scores of children with CI. As shown in Table 3, Spearman's rho revealed a statistically significant relationship (strong correlation) between receptive vocabulary and non-word repetition scores (rs[15] = .75, p < .01). Moreover, non-word repetition scores were significantly correlated with digit span scores (rs[15] = .65, p <.01) and with length of use of the implant (rs[15] = .56, p<.05). For the CA control group, there was only one statistically significant relationship between non-word repetition and rapid naming scores (rs[15] = -.52, p <.05). Thus, vocabulary was moderately correlated with digit span scores (rs[15] = .48, p=.07). For the younger PIA control group, vocabulary correlated significantly with both non-word repetition and digit span scores (rs[15] = .78, p<.01). Moreover, digit span was significantly correlated with non-word repetition (rs[15] = .58, p<.05).

Table 3. *Spearman's rho correlations among receptive vocabulary, non-word repetition and digit span scores for children with cochlear implants*

	Duration of CI use (in months)	**ROWPVT raw score %**	**Digit span raw score %**	**Non-word repetition correct syllables %**
Duration of CI use (in months)	1,000	,267	,364	,561*
ROWPVT raw score %	,267	1,000	,323	,745**
Digit span raw score %	,364	,323	1,000	,648**
Non-word repetition correct syllables %	,561*	,745**	,648**	1,000

Multiple linear regression analyses (see Table 4) were calculated for each of the three groups to predict receptive vocabulary skills (dependent variable) based on non-word repetition and digit span skills, length of use of the CI (only for the CI group) and non-verbal IQ (predictors). For children with CI, a significant regression equation was found, F(4, 10) = 6.87, p = .006 with an R^2 = .733. However, only non-word repetition percentage of syllables (Beta = 1.119, p = .001) was found to be a significant predictor, while digit span (Beta = -.222, p > .05), length of use of the CI (Beta = -.425, p > .05) and non-verbal IQ (Beta = .049, p > .05) were not.

For the CA control group, a non-significant regression equation was found, F(3, 11) = .858, p = .491 with an R^2 = .190. For the PIA control group, however, a significant regression equation was found, F(3, 11) = 9.875, p = .002 with an R^2 = .729. This time only digit span raw score (Beta = .571, p < .05) was found to be a significant predictor, while non-word repetition (Beta =

.440, p >.05) and non-verbal IQ (Beta = -.219, p >.05) failed to reach significance.

Table 4. *Multiple regression analyses modeling non-word repetition, digit span, use of CI and nonverbal IQ as predictors of receptive vocabulary in children with CI, and control groups CA and PIA.*

	CI[a]			CA[b]			PIA[c]		
Variable	B	SE B	β	B	SE B	β	B	SE B	β
non-word repetition	.754	.169	1.199	-.126	.227	-.154	.294	.141	.440
digit span	-.153	.167	-.222	.126	.090	.387	.367	.143	.571
use of CI	-.302	.155	-.425						
Raven	.022	.084	.049	-.096	.117	-.224	-.167	.134	-.219

[a]Adj R^2 = .733
[b]Adj R^2 = .190
[c]Adj R^2 = .729

Discussion

The findings of the present study showed that STM affects vocabulary learning in children with CI. Specifically, phonological STM affects vocabulary more than verbal STM. A stronger correlation between vocabulary and non-word repetition than between vocabulary and digit span was found. The regression analyses showed that performance on the non-word repetition task (phonological STM) strongly and specifically predicts vocabulary performance in children with CI.

For CA controls, there were only moderate correlations between vocabulary and digit span, while for PIA controls, vocabulary correlated with all measures and all measures correlated with one another. This is in accordance with the view of Gathercole et al. (1992) that in early childhood (about 4 years of age) STM skills exert a direct and probably causal influence on vocabulary skills, but this is not the case at a later age, such as the CA group in our study. In younger typically-developing children (PIA controls), digit span was the only variable found to predict vocabulary performance.

Thus, our results corroborate the view that in the NH population the contribution of STM to vocabulary acquisition is more evident in the early childhood (PIA controls) than in the middle childhood period (CA controls), in which children have better language and conceptual abilities and extensive spoken and written language exposure (Gathercole et al., 2005). Moreover, lexical acquisition in children with CI appears to be more influenced by phonological factors rather than auditory lexical processing.

References

Archibald, L., & Gathercole, S. (2007). Non-word repetition in specific language impairment: More than a phonological short-term memory deficit. *Psychonomic Bulletin & Review*, *14*(5), 919-924.
Baddeley, A. (2003). Working Memory and Language: An overview. *Journal of Communication Disorders*, 36, 189–208.
Bouton, S., Bertoncini, J., Serniclaes, W., & Colé, P. (2011). Reading and reading-related skills in children using cochlear implants: Prospects for the influence of cued speech. *Journal of deaf studies and deaf education*, *16*(4), 458-473.
Campbell, R., & Wright, H. (1990). Deafness and immediate memory for pictures: Dissociations between "inner speech" and "inner ear". *Journal of Experimental Child Psychology, 50*, 259-286.
Casserly, E., & Pisoni, D. (2013). Non-word repetition as a predictor of long-term speech and language skills in children with cochlear implants. *Otology & neurotology: official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, *34*(3), 460-470.
Gathercole, S., Tiffany, C., Briscoe, J., & Thorn, A. (2005). Developmental consequences of poor phonological short-term memory function in childhood: a longitudinal study. *Journal of Child Psychology and Psychiatry*, *46*(6), 598-611.
Gathercole, S., Willis, C., Emslie, H., & Baddeley, A. (1992). Phonological memory and vocabulary development during the early school years: A longitudinal study. *Developmental Psychology*, 28, 887–898.
Guasti, M., Papagno, C., Vernice, M., Cecchetto, C., Giuliani, A., & Burdo, S. (2012). The effect of language structure on linguistic strengths and weaknesses in children with cochlear implants: Evidence from Italian. *Applied Psycholinguistics, available on CJO2012.*
Harris, M., & Moreno, C. (2004). Deaf children's use of phonological coding: Evidence from reading, spelling, and working memory. *Journal of Deaf Studies and Deaf Education*, *9*(3), 253-268.
Harris, M., Kronenberger, W., Gao, S., Hoen, H., Miyamoto, R., & Pisoni, D. (2013). Verbal short-term memory development and spoken language outcomes in deaf children with cochlear implants. *Ear and Hearing*, *34*(2), 179-192.
Houston, D., Carter, A., Pisoni, D., Kirk, K., & Ying, E. (2005). Word learning in children following cochlear implantation. *The Volta Review*, *105*(1), 41-72.
Luckner, J., & Cooke, C. (2010). A summary of the vocabulary research with students who are deaf or hard of hearing. *American Annals of the Deaf*, *155*(1), 38-67.
Martin, N. & Brownell, R. (2000). *Receptive One-Word Picture Vocabulary Test* – 3rd Edition (ROWPVT-3). Novato, CA: Academic Therapy Publications.
PAL [Panhellenic Association of Logopeadics] (1995). Assessment of phonetic and phonological development. Athens: PAL.
Paraskevopoulos, I. Kalatzi-Azizi, A. & Giannitsas, N. (1999). Athena Test for assessing learning disabilities [in Greek]. Athens: Ellinika Grammata.
Pisoni, D., Kronenberger, W., Roman, A., & Geers, A. (2011). Article 7: Measures of digit span and verbal rehearsal speed in deaf children following more than 10 years of cochlear implantation. *Ear and Hearing*, *32*(1), 60s-74s.

Raven, J. (1947). *Raven's Progressive Coloured Matrices Standard*. E.A.P., Issy-les-Moulineaux (rééd. 1981).
Sprenger-Charolles, L., Colé, P., Béchennec, D., & Kipffer-Piquard, A. (2005). French normative data on reading and related skills from EVALEC, a new computerized battery of tests (end Grade 1, Grade 2, Grade 3, and Grade 4). *Revue Européenne de Psychologie Appliquée/European Review of Applied Psychology*, *55*(3), 157-186.
Talli, I. (2010). *Linguistic abilities in Developmental Dyslexia and Specific Language Impairment: A comparative and cross-linguistic approach*. Doctoral dissertation. Paris Descartes University and Aristotle University of Thessaloniki.
Willems, P., & Leybaert, J. (2009). Phonological Short term memory in deaf children fitted with a cochlear implant: effects of phonological similarity, word length and lipreading cues. *Revista de Logopedia, Foniatría y Audiología*, *29*(3), 174-185.