NIH Public Access
Author Manuscript
Ann Otol Rhinol Laryngol Suppl. Author manuscript; available in PMC 2012 August 28.

Published in final edited form as:
Ann Otol Rhinol Laryngol Suppl. 2000 December ; 185: 92–93.

WORKING MEMORY IN DEAF CHILDREN WITH COCHLEAR IMPLANTS: CORRELATIONS BETWEEN DIGIT SPAN AND MEASURES OF SPOKEN LANGUAGE PROCESSING

David D. Pisoni, Phd and **Ann E. Geers, Phd**
Department of Otolaryngology–Head and Neck Surgery, Indiana University School of Medicine, Indianapolis, Indiana (Pisoni); and the Center for Applied Research on Childhood Deafness, Central Institute for the Deaf, St Louis, Missouri (Geers).

INTRODUCTION

One of the most important problems in the field of pediatric cochlear implants is understanding the enormous individual differences in performance among children on a wide variety of outcome measures that assess speech perception, language comprehension. speech intelligibility, and reading. Some deaf children with cochlear implants do very well on standardized audiological and language tests and appear to be well on their way to acquiring spoken language through their implants, whereas other children do much more poorly and apparently never appear to reach these critical milestones in speech and language development.[1] What is the basis for these individual differences? Recent findings suggest that one factor may be related to the perceptual processing of spoken words, that is, the encoding, storage, and retrieval of the phonological representations of spoken words, and the use of working memory and rehearsal mechanisms.[1,2] To examine the role of working memory in speech perception, word recognition, speech production, language, and reading tasks, we obtained auditory digit spans from 8- and 9-year-old prelingually deaf children who had used their implants for a period of at least 4 years, then computed correlations between digit span and 4 sets of outcome measures.

METHODS

Participants

The memory span data were collected by Geers et al from 43 prelingually deaf children who were between 8 years and 9 years 11 months of age as part of their study of long-term cochlear implant users (this supplement, pp 89-92). All children hold used their cochlear implants for more than 4 years (mean, 5.5 years). Approxtimately half of the children were from oral-only programs, and half were from total communication (TC) programs. The two groups did not differ significantly in IQ, age at onset of deafness, duration of deafness, age at implantation, or length of implant use. The two groups did differ in the number of hours of speech and language therapy they received during the first 3 years after implantation. The oral-only group received a mean of 81 hours of speech therapy per year, whereas the TC group rcceived 42 hours.

Materials and Procedure

All children completed a 6-hour battery of tests distributed over 3 days 10 measure the 4 outcome variables: speech perception. speech production, language, and reading. The mean scores on these tests have been reported by Geers et al (this supplement, pp 89-92). In addition to this battery of tests, forward and backward auditory digit spans were also collected for each child by means of the digit span subtests of the Wechsler Intelligence

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Scale for Children (WISC-III).[3] The digit spans were obtained by means of live-voice presentation at a rate of approximately one item per second with lip-reading cues available. The child was presented with a list of digits and was asked to recall the items on the list in the correct lemporal order. Digit span was defined as the longest length sequence of digits that the child could recall correctly 2 times in a row.

RESULTS

Forward digit spans were correlated with the 4 sets of outcome measures obtained by Geers et al (this supplement, pp 89-92): speech perception, speech intelligibility, language, and reading. A summary of these correlations is displayed separately in the Table for each set of outcome measures.

Speech Perception

The simple correlations between digit span and the spoken word recognition measures were all positive and strong, especially for the closed-set WIPI test (r = +.71) and the open-set LNT (r = +.64), in which the words were presented in isolation. The correlation was also strong for words in Bamford-Kowal-Bench (BKB) sentences (r = +.59). Digit span was also positively correlated with the Children's Visual Enhancement test score (r = +.66), which measures the additional gain Ibat lip-reading provides the listener over auditory-only presentation. Partial correlations were then computed with the variance from speech feature discrimination on the Video Speech Pattern Contrast test (VIDSPAC) removed. These partial correlations and total variance are also given in the Table. Except for the BKB, the partial correlations are still statistically significant. suggesting the presence of an independent source of variance associated with memory that is separate from audibility or speech feature discrimination.

Speech Production

The Table also shows the correlation of digit span with a measure of speech intelligibility obtained with the McGarr sentences. These sentences were presented to adult listeners who were asked to transcribe what they heard each child say. The simple correlation is +.69. The partial correlation with the VIDSPAC removed drops to +.48, but this still remains significant.

Language

The correlations of digit span with 2 language measures – the WISC-III Similarities Subtest, which measures vocabulary use and abstract reasoning, and the Test for Auditory Comprehension of Language, which measures receptive language comprehension – are also shown in the Table. Both correlations are positive and moderate, indicating a contribution of working memory to processing of spoken words and sentences.

Reading

Correlations of digit span and the 4 measures of reading performance are also given in the Table. Again, the correlations are moderate and statistically significant for all 4 tests of reading.

DISCUSSION

The correlations between auditory digit span and the 4 sets of outcome measures obtained from these children suggest that some component of working memory plays an important role in mediating performance across a range of different tasks. Moreover, this component of memory contributes a common underlying source of variance to tasks that measure

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

speech perception, speech production, language comprehension, and reading. The commonality among the processes used in these tasks appears to be related to phonological coding and rehearsal processes used to encode and retrieve the representations of spoken words from lexical memory. The differences in performance among cochlear implant users on these 4 outcome measures may reflect fundamental differences in the speed and efficiency of elementary information processing operations that are used in the encoding, rehearsal, retrieval, and manipulation of the phonological representations of spoken words.

The identification of working memory as the "locus" of the differences in performance between children with cochlear implants also suggests that what the child does centrally with the information received through a cochlear implant may be just as important as the nature of the sensory information and the initial neural representations of speech signals at the periphery. This account of the differences in performance not only explains the pattern of correlations of digit span with the language-based outcome measures. but also provides a processing mechanism that can be used to understand the effects of early auditory experience on development and the substantial effects of communication mode that Geers et al (this supplement, pp 89-92) found on almost all of the outcome measures. Oral-only children are not only exposed to more speech and language during their daily activities (see, for example, Hart and Risley[4]), but they are also engaged in more meaningful processing activities that require them to use spoken language to construct robust phonological representations of the sound patterns of words in their language.[4]

Taken together, our results suggest that spoken language processing and working memory are closely interconnected and share common reciprocal links, connections, and processing resources that are used in speech, perception, speech production, language comprehension, and reading.

Acknowledgments

This study was supported by grants ROI DC00011, DC00064, DC00423, and DC03100 from the National Institutes of Health/National Institute on Deafness and Other Communication Disorders.

References

1. Pisoni, DB.; Svirsky, MA.; kirk, KI.; Miyamoto, RT. Looking at the stars: a first report on the interrelations among measures of speech perception, intelligibility and language in pediatric cochlear implant users.. Presented at the Fifth International Cochlear Implant Conference; New York, NY. May 1-3, 1997;
2. Baddeley A, Gathercole SE, Papagno C. The phonological loop as a language learning device. Psych Rev. 1998; 105:158–73.
3. Wechsler, D. Wechsler Intelligence Scale for Children. 3rd ed.. The Psychological Corporation; San Antonio, Tex: 1991.
4. Hart, B.; Risley, TR. Meaningful differences in the everyday experience of young American children. Paul H Brookes; Baltimore, Md: 1995.

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

CORRELATIONS WITH AUDITORY DIGIT SPAN

	r	Partial r
Speech perception		
Closed-set tasks		
WIPI	+.71	+ 50
Open-set tasks		
LNT	+.64	+.37
BKB	+.59	+.28
Auditory + visual		
CHIVE	+.66	+.45
Speech production		
McGarr Sentences		
Transcription	+.69	
Language		
WISC Similarities	+.52	
TACL	+.54	
Reading		
Woodcock Word Attack	+.62	
PIAT		
Vocabulary	+.59	
Comprehension	+.41	
Rhyme	-.48	

WIPI — Word Intelligibility by Picture Identification. LNT— lexical Neighborhood Test, BKB — Bamford-Kowal-Bench sentences, CHIVE — Children's Visual Enhancement test, PIAT — Peabody Individual Achievement Test.