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Digit span recall error analysis in pediatric cochlear implant users

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Abstract

The errors made by 37 pediatric cochlear implant users and age-matched normal-hearing children during forward and backward digit span recall were analyzed. All children were between 8 and 10 years old. The children who used implants had at least 4.5 years of experience with their device. Error classification was made using four categories: item, order, omission, or combination errors. Recall of digits not presented on a given trial was classified as item errors. The recall of all correct digits in an incorrect order was considered to be an order error. Results from a univariate ANOVA revealed main effects for error type, recall condition, and hearing ability. In addition, the error type by recall condition interaction revealed that order errors increased more in backward digit span recall than any other type of error for both normal-hearing children and children with cochlear implants. The present results are consistent with previous studies, suggesting that the shorter digit spans of children using cochlear implants are not primarily related to perceptual difficulties but appear to reflect memory processing problems related to slower subvocal verbal rehearsal and serial scanning of items in short-term memory.

Keywords

Cochlear implant; Deafness; Memory; Speech perception

1. Introduction

Recent studies examining auditory and visual memory spans have shown that children using cochlear implants have shorter memory spans than their normal-hearing peers. Their shorter spans may be a result of less efficient memory processes such as subvocal verbal rehearsal and serial scanning of items in short-term memory [1–3]. However, perceptual or auditory encoding errors specific to auditory digit span recall have not been as thoroughly investigated, and it is currently unknown how much of a contribution perceptual errors play in auditory memory span tasks compared to memory processing errors.

It is important to assess the contribution of perceptual difficulties in auditory memory tasks, because deaf children with cochlear implants may be making errors during the task simply because they are unable to perceive all of the stimuli correctly. Therefore, auditory memory tasks may underestimate the memory spans of deaf children using cochlear implants.

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Although stimulus identification tasks have been used prior to administering some auditory memory tasks in deaf children with cochlear implants [2], no attempts have been made to identify and quantify the types of errors made during serial recall tasks such as digit span. However, the types and patterns of errors made in auditory memory span tasks have been specifically defined and examined in normal-hearing populations under both normal [4], and degraded auditory conditions [5] which provides a useful framework in which to study this problem in deaf children who use cochlear implants.

2. Materials and methods

Thirty-seven normal-hearing children and deaf children using cochlear implants were studied. Twenty-five of the children were male, and 12 were female. The normal-hearing children were all monolingual native speakers of English and passed a brief hearing screening. The children using cochlear implants were determined to have normal intelligence based on Wechsler Intelligence Scale for Children (WISC) scores [6].

The WISC forward and backward digit span tests were administered to all children using live voice presentation by a trained clinician or the first experimenter. During the forward digit span task, the children were asked to repeat back the digits in the exact order they heard them. In the backward digit span task, children were asked to repeat the list in the reverse order. Forward digit span was measured first followed by backward digit span. Testing proceeded until the children incorrectly repeated two lists at the same list length. The children's responses were recorded onto digital audio tape and were also orthographically transcribed.

The errors made by the children during the digit span tasks were classified into four categories. The four categories of errors were item, order, omission, and combination. Errors were classified as item errors if a digit(s) that was not present in the list was repeated. Errors were considered to be order errors if all the correct digits were repeated but in an incorrect order. If a digit(s) was omitted from the list, the error was classified as an omission. Finally, when two or more of these three errors occurred within one list, a combination error was recorded.

3. Results

The results of a univariate ANOVA revealed three main effects. There was a main effect of error type ($F(4,584)=25.52, p=0.000$). Post hoc Tukey tests indicated that order errors occurred more frequently than any other type of error. A main effect of recall order indicated that more errors occurred in the backward recall condition ($F(1,584)=19.86, p=0.000$). Finally, there was a main effect of hearing ability demonstrating that deaf children who use cochlear implants committed more errors than their normal-hearing peers in both the forward and backward digit span recall task ($F(1,584)=4.08, p<0.05$).

An interaction between error type and recall order was also obtained ($F(3,584)=11.27, p=0.000$). This interaction revealed that order errors increased more in the backward digit span condition than any other type of error. Fig. 1 illustrates the pattern of errors obtained in both forward and backward digit span recall for the deaf children using cochlear implants and their normal-hearing peers.

4. Discussion

Deaf children who use cochlear implants make more errors overall in auditory digit span tasks than normal-hearing children. This finding was expected, given that deaf children using cochlear implants have previously been found to have shorter digit spans [1,2].

However, the pattern of errors made by deaf children using cochlear implants is similar to the pattern observed in their age-matched peers. Both deaf and normal-hearing children commit more order errors during digit span recall, particularly in backward digit span recall. Both groups of children may be more susceptible to order errors during backward digit span recall because it is a more complex task involving more sophisticated planning, rehearsal, and recall strategies involving executive function which may increase cognitive load [7].

In a serial recall task, difficulties in maintaining sequential order information are likely related to an increased cognitive load. Although the deaf children's sensory impairment does not appear to be the primary influence on digit span errors, it may cause an increase in cognitive load that contributes to order errors.

The results of this study indicate that even though deaf children with cochlear implants receive degraded auditory stimuli, their auditory memory spans are more adversely affected by errors in retaining sequential order information rather than by perceptual errors of individual list items.

This study reconfirms the earlier findings that deaf children using cochlear implants have shorter digit spans than their normal-hearing peers due primarily to errors or difficulties in processing. Subvocal verbal rehearsal and serial scanning are the two memory processes that have previously been determined to play a role in the shorter digit spans of deaf children using cochlear implants [1].

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Fig. 1. Mean proportion of errors made by pediatric cochlear implant users and normal-hearing children during (a) forward and (b) backward digit span recall. Error bars represent the standard error of the mean.