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Visual attention, behavioral inhibition and speech/language outcomes in deaf children with cochlear implants

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Abstract

We investigated relations between sustained visual attention, behavioral inhibition skills, and speech–language outcomes in prelingually deaf children who use cochlear implants (CIs) using two computerized continuous performance tasks (CPTs). One test measured their ability to sustain visual attention to a string of numbers and another test measured their ability to delay a behavioral response. Performance on latter task was related to postimplant scores on tests of vocabulary knowledge, language skills, and speech intelligibility. We conclude that behavioral inhibition skills of prelingually deaf children are related to several audiological outcome measures in deaf children with CIs. Our findings suggest that further investigation is warranted into executive functions and subvocal rehearsal skills of deaf children with CIs.

Keywords

Cochlear implant; Visual attention; Behavioral inhibition; CPT; Executive function; Predictor; Children; Outcome; Deafness

1. Introduction

Cochlear implants (CIs) enable many prelingually deaf children to obtain significant gains in spoken language skills [1, 2], although outcomes are variable [3, 4]. A portion of this variability might be explained by studying the underlying cognitive functions in these children who have experienced a period of prelingual auditory deprivation [5].

Earlier studies have demonstrated that deaf individuals may be more impulsive [6–9], and have difficulty sustaining visual attention [10–13], compared to normal hearing peers. There is evidence that auditory stimulation with a CI may lead to more typical development of attention in profoundly deaf children [10, 12]. It has been suggested that these effects are mediated by cross-modal changes in the attention system and/or changes in phonological encoding and working memory [12, 13].

Little is known about whether attention and behavioral control skills of deaf children with CIs are related to speech–language outcomes. Externalizing behavior problems have been associated with poorer speech–language skills in deaf children with CIs [14], and one study found a relationship between sustained visual attention ability and speech perception

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outcomes in postlingually deaf adults with CIs [15]. We examined performance of prelingually deaf children with CIs on two laboratory measures involving sustained visual attention or behavioral inhibition to determine whether these skills were related to outcomes over 3 years of CI use.

2. Method

2.1. Subjects

We conducted a retrospective analysis of clinical data gathered at the Indiana University School of Medicine Cochlear Implant Progiam. We identified 47 children with prelingual deafness who had received a CI by 9 years old and were tested at least once on the sustained visual attention test and/or the behavioral inhibition task. All children had Nucleus 22 devices and approximately 50% participated in auditory/oral therapy (50% used total communication). Mean age of implantation was 4.8 years old.

2.2. Procedures

Sustained visual attention was assessed using a vigilance continuous performance task (vCPT) in which children monitored a sequence of numbers on an LED display for 6 min. They were scored based on accuracy for responding only to a designated target number by pressing a button. Dependent measures were hit rate and false alarm rate. Behavioral inhibition was assessed using a delay task (dCPT) in which children were required to make sequential button presses with an unspecified delay between presses. Each time two button presses were separated by at least 4 s a visual score counter registered a point. Children had 6 min to figure out the delay rule based on this feedback. The ratio of correct delays to total button presses was the dependent measure for this task. Most children were given the CPTs after 1 year of CI use although length of CI use at time of CPT testing varied from 1–3 years.

Audiological outcome data included several standard measures collected every 6 months collapsed into three intervals of CI use: 1, 2, and 3 years. Open set speech perception was assessed by the Phonetically Balanced Kindergarten test for phonemes and words [16]. Open set sentence comprehension was assessed with the Common Phrases test [17] which was administered in auditory, visual, and audiovisual modalities. Vocabulary knowledge was measured with the Peabody Picture Vocabulary Test, and receptive and expressive language skills were assessed by the Reynell Developmental Language Scales 3rd edition [18, 19], and were administered using the child's preferred mode of communication (oral or manual). Finally, speech intelligibility was assessed using the Beginner's Intelligibility Test [20], All tests were administered by experienced clinicians in a quiet room with instructions given in the child's preferred mode of communication.

3. Results

Bivariate correlations were carried out between each CPT and outcome measures obtained after 1, 2, and 3 years of CI experience. No significant relations were found between the vCPT and any of the outcome measures. In contrast, bivariate correlations were significant between the dCPT and several outcome measures.

Correlations between the dCPT and vocabulary and language measures were strong and highly significant ($p<0.01$) at most intervals of CI use. Correlations between the dCPT and speech intelligibility were more modest and significant only to the $p<0.05$ level. For these relations, we conducted partial correlations to control for chronological age and length of CI use at the time of CPT testing. Relations between dCPT and vocabulary/receptive language remained significant at all but one interval while relations between dCPT and expressive

language/intelligibility remained significant only at 1 year post implantation. A correlation matrix for these findings is shown in Table 1.

4. Discussion

Our findings suggest that behavioral inhibition skills as measured by the dCPT are related to vocabulary knowledge and receptive language skills over 3 years of CI use. Behavioral inhibition skills were also related to expressive language and intelligibility skills after 1 year of use but these relations were not found in children tested after 2 or 3 years of use. In contrast, no relations between the vCPT task and outcomes were uncovered.

The different results we obtained with the two CPTs indicate that they are sensitive to different cognitive skills in the deaf children we tested. Performance on the dCPT might be more influenced by subvocal rehearsal strategies which are related to speech perception, production, and language measures in deaf children with CIs [21–23]. Another possibility is that the dCPT loads more heavily than the vCPT on executive functions including behavioral analysis and synthesis. More research is needed to better understand how these functions play a role in deaf children acquiring speech–language skills with a CI.

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Table 1

Significant bivariate correlations between dCPT error ratio and outcomes

Outcome measure	Postimplant year 1	Postimplant year 2	Postimplant year 3
Vocabulary	**0.69 (34)++**	**0.62 (35)++**	**0.55 (31)**
Receptive language	**0.60 (32)+**	**0.64 (29)++**	**0.61 (27)++**
Expressive language	**0.54 (32)**+	**0.61 (25)**	0.46 (27)
Speech intelligibility	0.42 (30)+	0.38 (32)	NS

Significant bivariate correlation coefficients are shown in bold type ($p<0.01$) or plain type ($p<0.05$).

Plus signs indicate that these relations remained significant at the $p<0.05$ level (+) or the $p<0.01$ level (++) when the effects of chronological age and length of CI use at time of dCPT testing were partialled out. Age equivalent outcome scores were used for the above measures except for speech intelligibility in which percent correct scores were used.