Published in final edited form as:
Int Congr Ser. 2004 November 1; 1273: 356–359. doi:10.1016/j.ics.2004.07.049.

Visuomotor integration ability of pre-lingually deaf children predicts audiological outcome with a cochlear implant: a first report

David L. Horn[a,*], **Rebecca A.O. Davis**[a], **David B. Pisoni**[a,b], and **Richard T. Miyamoto**[a]

[a]DeVault Otologic Research Laboratory, Department of Otolaryngology/Head and Neck Surgery, Indiana University School of Medicine, Riley Research Wing Rm 044, 699 West Drive, Indianapolis, IN 46202, United States

[b]Department of Psychology, Indiana University, Bloomington, IN, United States

Abstract

We investigated the predictive relations between pre-implant visuomotor integration ability and subsequent oral speech/language outcomes in prelingually deaf children who use cochlear implants (CIs). Prior to implantation, children were given a task that tested their accuracy in copying geometric forms. Performance on this task predicted speech perception, sentence comprehension, and speech intelligibility outcomes over 3 years of CI use. We conclude that individual differences in visuomotor integration ability are predictive of some audiological outcome measures in deaf children with CIs.

Keywords

Cochlear implant; Visuomotor integration; Predictor; Children; Outcome; Deafness

1. Introduction

Cochlear implants (CIs) enable many prelingually deaf children to acquire spoken language skills [1,2], although clinical outcomes are extremely variable [3,4]. Although several factors have been identified as pre-implant predictors of performance in these children, a large part of this variance remains unexplained [3].

It is recognized that perceptual motor development is closely tied to the emergence of spoken language in normal hearing children and children with hearing loss [5–9]. Some studies have suggested that early deafness is associated with atypical development of visuomotor skills such as figure copying/drawing and catching [10,11]. We examined whether visuomotor skills of deaf children were predictive of speech and language outcomes with a CI.

2. Methods

We conducted a retrospective analysis of longitudinal clinical data gathered at the Indiana University School of Medicine Cochlear Implant Program. Inclusion criteria were: profound deafness by 3 years old, implantation before 9 years of age, completion of a test of

*Corresponding author. Tel.: +317 274 1985; fax: +317 274 4949. dlhorn@iupui.edu (D.L. Horn).

visuomotor integration skill prior to implantation. A total of 42 children (18 females, 24 males) were identified for the study. Mean age of implantation was 5 years old (SD=20 months). Seventeen children were in auditory-oral therapy programs and 25 used total communication. No children had known cognitive or motor delays.

2.1. Procedures

Prior to implantation, children were tested using the Beery Developmental Assessment of Visuomotor Integration (VMI, [12]). The VMI is a sequence of 24 geometric forms of increasing complexity from a simple vertical line to a complex three-dimensional star. Children are scored based on their ability to accurately copy these forms by drawing. Age equivalent scores are based on normative data from thousands of normal hearing children. We divided each child's age equivalent score by their chronological age at the time of testing to derive a VMI quotient (VMIq) so that a score of 1 reflected typical performance at any age.

Audiological outcomes were assessed by several tests that are routinely collected every 6 months from children in our research program. These scores were collapsed into 4 intervals of CI use: pre-implant, 1,2, and 3 years. Live-voice, open set speech perception was assessed by the Phonetically Balanced Kindergarten test (PBK) [13]. Live-voice, open set sentence comprehension was assessed with the Common Phrases (CP) test [14] and was administered in auditory, visual, and auditory plus visual modalities. Four-choice closed set vocabulary knowledge was measured with the Peabody Picture Vocabulary Test (PPVT) [15], and receptive and expressive language skills were assessed by the Reynell Developmental Language Scales (RDLS) 3rd edition [16]. Both the PPVT and RDLS were administered using the child's preferred mode of communication (oral or manual) and age equivalent scores were used in our analyses. Finally, speech intelligibility was assessed using the Beginner's Intelligibility Test [17]. Experienced clinicians administered these tests in a quiet room.

3. Results

Mean VMIq was 0.98 (SD=0.21) and the individual scores were normally distributed. To assess whether pre-implant VMIq scores were predictive of post-implant outcomes, we constructed a longitudinal mixed model in which between subjects factors were chronological age (at time of VMI testing) and VMIq score. The repeated measures factor was length of CI use (pre-implant, 1,2, 3 years). Separate statistical models with this design for each audiological outcome measure using the SAS statistical package [18].

We found significant effects of chronological age and length of CI use on all outcome measures and these results will not be discussed further. We also found a significant main effect of VMIq on PBK words ($p<0.05$), PBK phonemes ($p<0.01$), auditory CP ($P<0.01$), and audiovisual CP ($p<0.01$), Mean performance of children in the top 50th percentile for VMIq in our sample was consistently superior to those in the bottom 50th percentile as illustrated in Fig. 1a–d. No effects or interactions involving VMIq were found on the PPVT or the RDLS.

For speech intelligibility, we found a significant three-way interaction between VMIq, chronological age, and length of CI use as illustrated in Fig. 2. Children were split into two age groups based on the median age of our sample. The effect of VMIq on speech intelligibility scores was greater for younger children than for older children.

4. Discussion

Visuomotor integration skills of prelingually deaf children who present for a CI do not appear to be atypical compared to normative data. Individual differences in VMI skills in these children are predictive of speech perception, sentence comprehension, and speech intelligibility skills, which emerge over 3 years of CI experience. For speech intelligibility, the predictive value of the VMI is greater in younger children than older children after 2 and 3 years of CI use. Our results provide promising evidence that pre-implant assessment of deaf children's perceptual motor skills may be clinically useful.

Our findings do not reveal the neuro-cognitive mechanisms behind this relationship and more research is warranted. Drawing and copying skills likely tap a number of cognitive functions including motor planning, executive functions, visuo-spatial cognition and working memory. Examination of these skills in deaf children with CIs may inform this research area.

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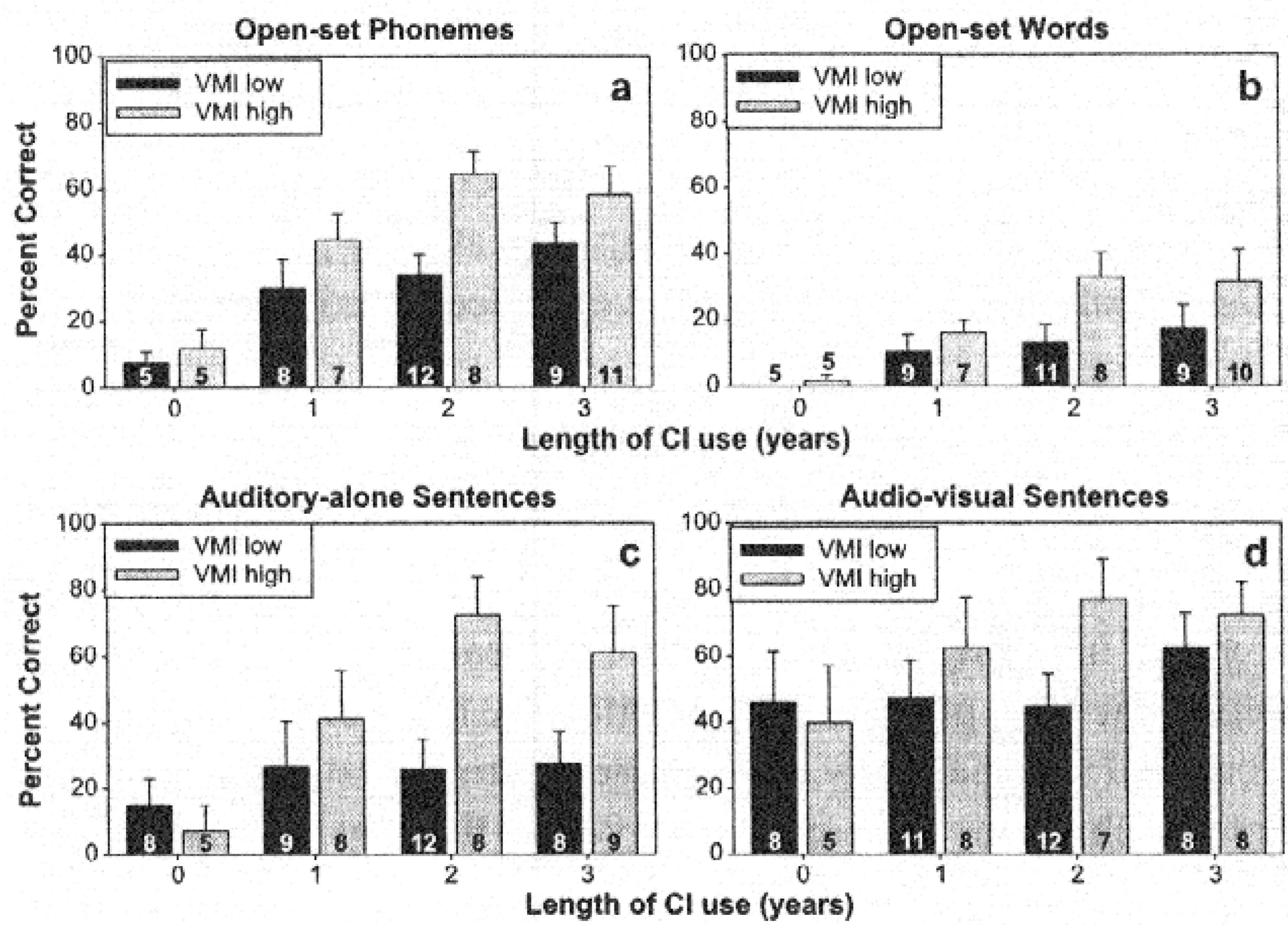

Fig. 1.
Mean Performance on PBK (a, b) and CP (c, d) tasks as a function of length of CI use and pre-implant VMI q median split group. Children who had VMI q scores in the upper 50th of our sample show higher performance on these measures than children who scored in the lower 50th percentile on the VMI.

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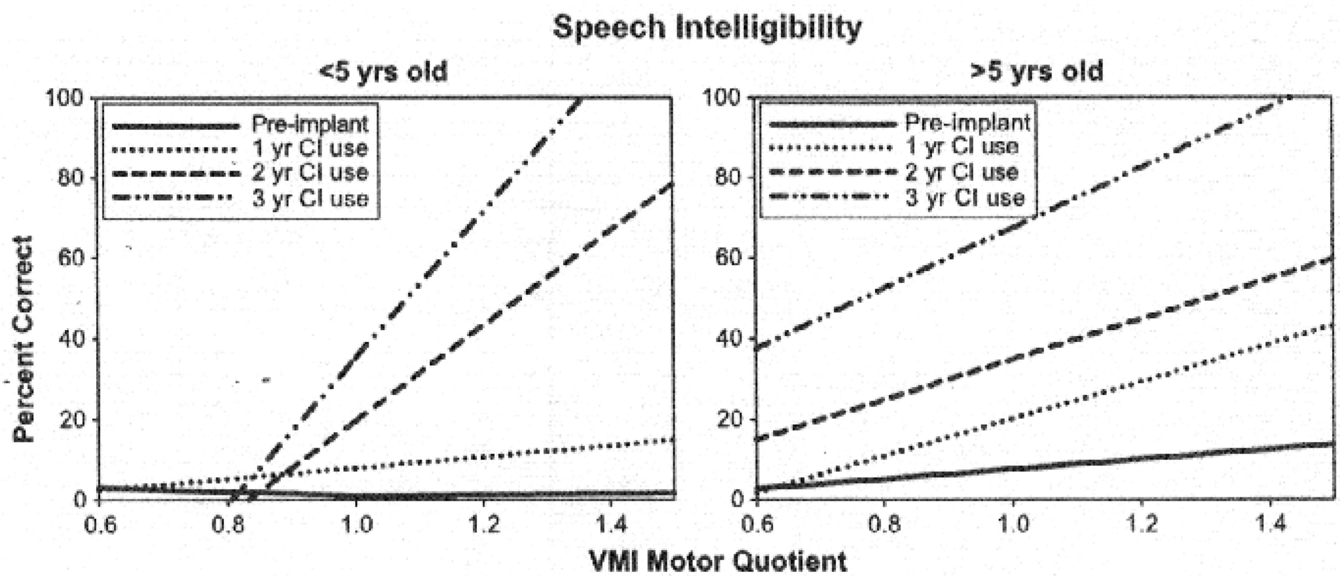

Fig. 2.

We divided our sample of children into two groups based a median split for chronological age at the time of VMI testing (4 years 10 months). Each line represents mean performance at a specific interval of CI use and were computed using slopes obtained from the SAS mixed model. Older children show greater effect of VMI q than younger children after 1 year of CI use. However, younger children appear to show greater effect of VMI q after 2 and 3 years of CI use, possibly due to floor effects of the BIT in the youngest children.