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Reading instead of reasoning? Predictors of arithmetic skills in children with cochlear implants☆

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ABSTRACT

Objectives: The aim of the present study was to evaluate whether the arithmetic achievement of children with cochlear implants (CI) was lower or comparable to that of their normal hearing peers and to identify predictors of arithmetic achievement in children with CI. In particular we related the arithmetic achievement of children with CI to nonverbal IQ, reading skills and hearing variables.
Methods: 23 children with CI (onset of hearing loss in the first 24 months, cochlear implantation in the first 60 months of life, atleast 3 years of hearing experience with the first CI) and 23 normal hearing peers matched by age, gender, and social background participated in this case control study. All attended grades two to four in primary schools. To assess their arithmetic achievement, all children completed the "Arithmetic Operations" part of the "Heidelberger Rechentest" (HRT), a German arithmetic test. To assess reading skills and nonverbal intelligence as potential predictors of arithmetic achievement, all children completed the "Salzburger Lesetest" (SLS), a German reading screening, and the Culture Fair Intelligence Test (CFIT), a nonverbal intelligence test.
Results: Children with CI did not differ significantly from hearing children in their arithmetic achievement. Correlation and regression analyses revealed that in children with CI, arithmetic achievement was significantly (positively) related to reading skills, but not to nonverbal IQ. Reading skills and nonverbal IQ were not related to each other. In normal hearing children, arithmetic achievement was significantly (positively) related to nonverbal IQ, but not to reading skills. Reading skills and nonverbal IQ were positively correlated. Hearing variables were not related to arithmetic achievement.
Conclusions: Children with CI do not show lower performance in non-verbal arithmetic tasks, compared to normal hearing peers.

1. Introduction

Mathematical key competences are of great importance for professional and academic success of individuals and society as a whole. Mathematical achievement in early childhood strongly predicts school achievement in the long term until college [1]. Poor numeracy skills disadvantage people, especially women [2], in everyday life resulting in additional costs for the national economy [3].

In normal hearing children, mathematics achievement at school is strongly dependent on intelligence, in particular on (nonverbal) logical reasoning abilities [4,5]. Difficulties in mathematical problem solving have been observed in students with social disadvantages [6,see also 1] or reading problems [7].

Numerous studies indicate that deaf and hard of hearing (DFHH) children and adolescents without cochlear implants (CI) score lower in mathematical tasks than their normal hearing peers [8–17]. Unless otherwise specified, the term DFHH children will be used throughout the text to refer to children with mild to profound hearing loss, who have not been implanted with CI. These findings apply to children and adolescents with sign language (as preferred communication) [8–13] as well as children and adolescents with spoken language [9,14,15] and children and adolescents with sign supported speech [9].

Already at a very young age, DFHH children are left behind in mathematics by their normal hearing peers [11,12,15]. Three to six year old DFHH children, growing up with sign language, have problems to count in sign language, even if their parents are fluent signers [11]. These problems in counting may be explained by the

☆ This study was performed at the Department of Otorhinolaryngology, Head and Neck Surgery, University Clinic, Salzburg, Austria.

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structure of number sequences in sign languages (e.g., Belgian number signs follow a base-5 rule) [11]. However, four to six year old DFHH children with sign language as their preferred mode of communication are not only behind their normal hearing peers in counting, reading and writing of digits, but also in number comparisons, addition and subtraction of small numbers [12]. Children with deaf parents and with "fluent" exposure to sign language at home score better than children with hearing parents, but they still score below the norm of normal hearing children [12].

A study [15] about three to five year old DFHH children, growing up with spoken language, reports very similar results. The children were found to be behind their normal hearing peers in number understanding (e.g., counting), problem solving (e.g., simple story problems), and measuring (e.g., size, length, or time), even though most of them were using hearing aids [15].

The "math gap" [15] still exists when DFHH children first attend school, and continues throughout the college years [18]. A lag in mathematics achievement was reported for DFHH children and adolescents with sign language [8,10,13,16], as well as for DFHH children, with mostly spoken language [14]. It is estimated to be at least 2.5 years for deaf children (for children with a profound hearing loss) [10].

Some authors, e.g., [15] interpret this lag as a consequence of learning deficits. DFHH children have smaller chances to learn incidentally from the people in their environment than their normal hearing peers [15]. "Language barriers", caused by a hearing loss, may hinder DFHH children in understanding advices, explanations and other comments from their parents or early interventionists, who try to support their child [15]. Thus, it seems plausible that difficulties with mathematics in school aged DFHH children are also in part caused by language problems [19]. Indeed it has been demonstrated, that DFHH children throughout grades one to twelve have problems understanding mathematical terminology and following mathematics lessons at school [17], irrespective of whether they used sign language or spoken language as their preferred mode of communication. Speech or language impairments often result in reading difficulties, e.g., [20] which have been demonstrated to affect mathematical problem solving in normal hearing children [7].

However, so far (to our best knowledge) the role of reading problems of DFHH children in causing problems with mathematics has only been addressed by one single study [18].

The number of studies addressing the mathematics performance of DFHH children and adolescents with CI remains limited as well. Children with CI scored below average on math word problems of the WISC III [21–23], and a non-normed math learning system [22,24]. Furthermore, like DFHH children and adolescents without CI, Scottish children and adolescents with CI scored below normal hearing pupils in school attainment scores [9]. However, other studies report that children and adolescents with CI in mainstream schools score at or even above average in school examinations [25,26]. In none of the studies [22,23,25,26], was arithmetic achievement assessed language-independent, i.e., math word and story problems were included. Furthermore, none of these studies [22,23,25,26], addressed whether language or reading skills [7], were related to the differences observed between normal hearing children and children with CI. One study described the successful improvement of speech and language in DFHH children due to an auditory-verbal intervention program [27]. However, only some of the children were a CI and even though their data on reading and mathematics suggest comparable scores between DFHH children and normal hearing children, the sample size was too small for statistical inferences [27]. Also, none of the studies on children with CI [22,23,25,26], investigated whether hearing variables, such as the age at fitting of the first CI or duration of CI usage was related to arithmetic achievement of children with CI. However, such information is essential to provide successful intervention for DFHH children with and without CI. If we know exactly what the special needs of DFHH children are concerning mathematics education, we can create intervention programs, which are "straight to the point".

The present study aims to assess, whether the arithmetic achievement of children with CI is lower or comparable to that of their normal hearing peers when assessed by a standardized language-independent instrument. Furthermore, we seek to identify predictors of arithmetic achievement in children with CI as compared to predictors identified in normal hearing peers. In particular, we relate arithmetic achievement in children with CI and normal hearing children to non-verbal IQ, reading skills and hearing variables.

2. Methods

2.1. Participants

This observational study (case–control study) was embedded in a more comprehensive project on the cognitive and academic performance of children with CI from our clinic [28]. The project included 40 Austrian children with CI between 7 and 11 years of age. All implantations were performed at the University Clinic in Salzburg. Children were selected based on the following inclusion criteria: (i) onset (diagnosis) of hearing loss in the first 24 months of life, (ii) cochlear implantation in the first 60 months of life, and (iii) at least 3 years of hearing experience with the first CI.

Study group: As the "Heidelberger Rechentest" (HRT, see below) does only provide norms for primary schools, and the "Salzburger Lesetest" (SLS, see below) requires German as a native language, 23 (12 boys, 11 girls, mean age ± SD: 9.77 ± 1.09 years) primary school pupils (6 grade 2, 6 grade 3, 11 grade 4) with German as a native language from the original sample of 40 children with CI participated in the arithmetic study. Audiological and anamnestic data are summarized in Table 1. Medical and audiological data were obtained from clinical files. Other demographic and hearing information was obtained from written interviews with the parents.

Comparison group: Test results of the "Programme of International Student Assessment" (PISA studies of the OECD, Organisation for Economic Co-operation and Development, https://www.bifie.at/pisa) over the past 5 years suggest that Austrian pupils' arithmetic performance lies below the German norm provided for the HRT (see below). Therefore, a comparison group of 23 Austrian pupils (12 boys, 11 girls, mean age ± SD: 9.38 ± 0.62 years) was selected from an original sample of 47 normal hearing primary school pupils (4 grade 2, 7 grade 3, 12 grade 4) with German as a native language to match the CI-group in gender, age, grade and social background. Social background variables for both groups are displayed in Table 2.

The study was approved by the local ethics committee, "Ethikkommission Salzburg". All parents gave their informed written consent for their children to participate in the study.

2.2. Instruments

The "Arithmetic Operations" part of the *"Heidelberger Rechentest" (HRT)* was employed to evaluate the arithmetic skills of CI-children and normal-hearing children [29]. The HRT is a validated and standardized speed-test battery for the assessment of basic mathematical achievement among primary school pupils. The "Arithmetic Operations" part includes six subtests: (i) addition (A: e.g., "16 + 27 = ?"), (ii) subtraction (S: e.g., "81 − 45 = ?"), (iii) multiplication (M: e.g., "8 × 17 = ?"), (iv) division (D: e.g., "124 / 4 = ?"), (v) number comparison (NC: e.g., "2 O 817−816" Is 2 bigger