Reading comprehension in Dutch school-aged children with cochlear implants

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Introduction

Since much of what will be learned at school is acquired by reading, reading comprehension is an important predictor of overall school performance. According to the Simple View of Reading model[1], reading comprehension is considered to be the product of decoding skills and linguistic comprehension. In learning to read, children start with acquiring decoding skills (i.e. sounding out the graphemes, blending them together into a word), and learn to apply decoding printed words with greater speed and accuracy. Subsequently, visual word recognition is becoming increasingly automated by recognition of words as wholes[2]. While decoding relies on spoken phonological knowledge, linguistic comprehension relies on spoken language skills such as word knowledge.

In the past, many children born with a severe to profound hearing loss, struggled with reading comprehension. Due to the hearing loss, they lacked sufficient access to sound, resulting in poor spoken phonological knowledge, which in turn affects the decoding skills, and poor spoken language skills[3,4]. Hence, most deaf children achieved very poor reading comprehension scores compared to hearing children[5–7].

Because cochlear implants (CI) provide deaf children access to auditory information, resulting in improved speech perception and enhanced language development, it was expected that children with CI would perform better on reading comprehension.

Previous studies[8,9] investigating reading comprehension in Dutch-speaking children with CI indicated that they performed significantly better than deaf children without CI, but still far below the norm for hearing children. However, children in both studies received CI respectively at the age of 6 and 4 years, which is now considered to be late.

Today, children born with a severe to profound hearing loss are diagnosed soon after birth, by which most of them receive CI early in life: often before the age of 3, but increasingly more children receive bilateral CI before 18 months. Studies have shown that early cochlear implantation and bilateral CI are associated with improved speech perception in soft speech and in noise[10–12], and with enhanced language performance[13–15], if no additional problems are present. As a result, more children with CI are now attending mainstream education[16].

With regard to reading comprehension, international studies[17–21], in which the mean age at implantation ranged from 1;04 to 3;05, demonstrated that more than half of the children with CI achieved scores within or above the normal range for hearing children, i.e. scores that lie between one SD below the mean and one SD above the mean. However, their performance appeared to be at the lower end of the normal range, and most studies reported a wide variability in scores.

Based upon these findings, it is hypothesized that age-appropriate reading comprehension scores are feasible for a substantial part of the present population of Dutch children with CI. However, no recent study has been reported. For parents, teachers and professionals in the

clinic, an update of the reading comprehension performance of children with CI is important. Firstly, to know what might be expected or strived for, secondly, to support the children according to their strengths and needs, and finally, to detect children at risk for poor school performance.

Therefore, the aim of the present study is to examine reading comprehension in Dutch children with prelingual severe to profound hearing loss who received their CI before the age of 3, and the variance in their performance. Because reading comprehension is a complicated skill, several child-related factors (age at implantation, educational placement, additional problems, uni- or bilateral CI, communication mode at home) and reading-related skills (word knowledge, reading skills at word level, and verbal memory) were examined.

This study addressed the following research questions:

a. How do Dutch school-aged children who received CI before age 3 perform on standardised tests for reading and word knowledge compared to hearing peers?
b. Which child-related factors and reading-related skills are associated with reading comprehension in children with CI?
c. To what extent can variance in reading comprehension in children after early cochlear implantation be explained by speech perception, child-related factors and reading-related skills?

Method and materials

This observational study, with a cross-sectional design, was performed between March and June 2015. It was part of the clinical evaluation protocol for the follow-up of children who received CI at the Ear Nose and Throat (ENT) Department, division Hearing and Implants of the Radboud University Medical Centre (UMC), Nijmegen. For this study already available data, and new collected data were used.

Participants

Participants were children who had a prelingual severe to profound hearing loss, and received CI before the age of 3 at the ENT Department of Radboud UMC in Nijmegen. All participants attended primary schools for children with normal intellectual abilities, either mainstream education or schools for deaf and hard-of-hearing (DHH) children.

For comparison with the performance of hearing children, reference data were used from the norm samples of typically developing children in primary education, published in the manuals of the standardized tests.

A total of 24 children, aged between 7;08 and 12;02 years, met the inclusion criteria. The mean age of the first implantation was 1;07 years, and half of the children used contralateral a second CI or a hearing aid (HA). Most children attended mainstream education (ME), and

used oral language in the communication at home. Five out of seven children, attending DHH schools, had additional problems such as behaviour problems and/or neurological problems. Two children had two deaf parents, and used Sign Supported Dutch (SSD) or Sign Language of the Netherlands (SLN) as communication mode at home.
Table 1 summarizes the main characteristics of the participants.

Insert Table 1 about here----------

Tasks and materials

Reading comprehension. Comprehension of written passages was assessed using the Reading comprehension tests of the Dutch Institute of Educational Measurement (CITO).[22] The raw score was transformed into a standard score, in order to compare the scores of children in different grades, and into an achievement level (decreasing from I to V).

Word knowledge. For most children, the Dutch version of the Peabody Picture Vocabulary Test (PPVT-III NL),[23] a standardised norm-referenced test was used to measure word knowledge. The raw score was transformed into a word knowledge quotient. For two children, the verbal intelligence quotient (VIQ) was used as word knowledge quotient, since the VIQ is an indication for word knowledge[23].

Reading skills at word level. To measure reading fluency and accuracy at word-level, two subtests of the Dutch version of the Dyslexia Screening Test (DST-NL)[24] were administered: the subtest *Non-word reading*, which measured the child's ability to decode non-existing words, and the *Word reading* subtest, which measured the child's ability to read real words. For each subtest, the raw score, i.e. the number of correctly read words, was transformed into a norm score.

Verbal memory. The task *Word span* of the Leidse Diagnostische Tests[25] (LDT) was used to measure the auditory short term memory (STM). Since the original task is meant for children aged 4 up to 8, three sequences of 6 words were added to make the task also suitable for older children (See Appendix). The task was stopped after 3 consecutive failures. After the raw score was transformed into an age-equivalent score, this age-equivalent score was divided by the child's chronological age to calculate a word span quotient.
The phonological memory was measured using the Dutch *Non-word repetition task*[26], consisting of 16 non-words of 2 to 5 syllables in length in random order. The child was asked to repeat all non-words, spoken aloud by the researcher. The responses were recorded

using a digital audio recorder, and transcribed afterwards. The percentage correctly repeated phonemes was computed.
Finally, the standardised subtest *Backward digit span* of the DST-NL[24] was administered to measure the auditory working memory (WM). The raw score was transformed into a norm score.

Speech perception in challenging listening situations. Wordlists of the Dutch Audiologists Association (NVA),[27] consisting of mono-syllabic consonant-vowel-consonant words, were used. For perception of soft speech, the words were presented at 45 decibels Sound Pressure Level (dB SPL). For speech perception in noise, the words were presented at 65 dB SPL together with speech-shaped noise at 65 dB SPL, so the signal-to-noise ratio (SNR) was 0 dB. The child was asked to repeat each word. For each condition, the percentage of correctly repeated phonemes was computed.

Procedure

The teachers of the participants provided the results on the reading comprehension test. Data concerning word knowledge were available in hospital files. Speech perception was administered at the ENT Department during the annual control visit by the audiologist. For the other tasks, the children were tested individually at the ENT Department or at school in a quiet room by the researcher. Tasks were administered in the same order for all children and a test session lasted a maximum of 30 minutes.

Data analyses

All statistical analyses were performed using statistics software IBM SPSS version 20 for Windows.[28] The significance level was set at .05. Missing data were handled by available case analysis. Because of the small number of participants, non-parametric test were used. As mentioned before, to compare test scores with those of hearing peers, reference data were used from the norm samples of typically developing children in primary education, published in the manuals of the standardized tests.
Descriptive statistics were reported for all variables by means and SD's, together with the percentage of scores that lie within or above the normal range. If a child obtained a score between -1 SD and +1 SD, the score was considered to fall within the normal range of hearing, typically developing children.
To compare the distribution of scores or categories with those of the norm sample, One-sample Kolmogorov-Smirnov tests and One-Sample Chi-Square tests were performed. For comparisons of performance by subgroups, Mann-Whitney U tests were used. Next, Spearman's rank correlations (one-tailed) were conducted to examine relationships between

reading comprehension, child-related factors, and reading-related skills. And finally, multiple regression analyses were performed to examine the contribution of child-related factors and reading-related skills to the variance in reading comprehension.

Results

Firstly, the performance of the participants was compared to that of hearing children. Secondly, relationships between reading comprehension and several child-related factors, and reading-related skills were examined, and finally the contribution of these factors and skills to the variance in reading comprehension.

Insert Table 2 about here----------

As shown in Table 2, the mean scores on reading comprehension, reading skills at word level, and word knowledge, were within one SD below the mean of the norm sample, and thus within the normal range. The mean score for verbal WM, evaluated with the Digit span backwards task, was also within the normal range, while the mean score for auditory STM, evaluated with the Word span task, was more than 2 SD below the mean of hearing children. Compared with the distribution of scores in the norm sample, the scores of the total group on reading comprehension, word knowledge, and STM differed significantly (resp. $p = .006$, $p = .001$ and $p = .000$). However, no significant differences with the norm sample were found in the distributions of scores for decoding, word recognition, and verbal WM (resp. $p = .660$ and $p = .342$ and $p = .106$).
50% of the total group obtained reading comprehension scores within or above the normal range (Figure 1), which is significantly less than the 84% in the norm sample ($p = .000$). However, 67% of the children in mainstream education achieved reading comprehension scores within or above the normal range, which did not significantly differ from the norm sample ($p = .187$). Only one out of the seven children in DHH schools, obtained a reading comprehension score within the normal range, and this distribution differed significantly from the norm sample ($p = .000$).

Insert Figure 1 about here----------

With regard to the achievement levels in the total group (Figure 2), 68.1% scored at the lowest levels (IV and V), which are considered unsatisfactory according to the standards of Dutch primary education, whereas two children performed at the highest level (I). As can be seen in the figure, more children attending mainstream education obtained satisfactory scores (levels I-III), compared to the number of children attending DHH schools.

Insert Figure 2 about here----------

Figure 3 provides boxplots with reading comprehension scores for subgroups classified by child-related factors. Children attending mainstream education achieved significantly higher scores than children at DHH schools ($p = .026$). No significant differences in reading comprehension scores were found for children who received CI before or after the age of 18 months ($p = .346$), for children with or without additional problems ($p = .494$), for children with unilateral or bilateral CI ($p = .295$) and for children using oral language or SSD/SLN at home ($p = .718$).

Insert Figure 3 about here----------

Correlational analyses confirmed the significant relationship between reading comprehension and educational placement, $r_s = -.478$, $p < .05$ (Table 3). No significant relationships were found between reading comprehension and the other child-related factors. However, educational placement was significantly related to additional problems ($r_s = .519$, $p < .01$). When reading comprehension scores of children in the two educational settings were compared, and additional problems were taken into account, the interaction effect between educational placement and having additional problems did not reach significance ($F(1,18) = .021$, $p = .888$). Thus, having additional problems was not a cascading factor in the differences in reading comprehension scores between children in mainstream education and DHH schools.

Insert Table 3 about here----------

Table 4 shows the correlation coefficients between reading comprehension and word knowledge, reading skills at word level, verbal memory and speech perception measures.

Insert Table 4 about here----------

Reading comprehension was significantly correlated with word knowledge, $r_s = .621$, and reading skills at word level, $r_s = .522$ for decoding, and $r_s = .632$ for word recognition. Word knowledge was also significantly correlated with decoding, $r_s = .533$, and word recognition, $r_s = .822$ (all $ps < .001$). These results indicate that children with higher scores for word knowledge and reading skills at word level, also obtained better reading comprehension scores. Reading comprehension was also significantly related to verbal WM, $r_s = .592$, $p <$

.001. A weak relationship was found between reading comprehension and speech perception at 45 dB, and speech perception in noise, resp. r_s =.123 and r_s =.281, both not significant, although both measures were strongly related to one another, r_s =.570, p < .001.
Because of the presence of strong significant correlations between the measures of word knowledge, reading skills at word level, and verbal WM, a factor analysis (Principle Component Analysis with varimax rotation) was conducted to extract a composite factor score that was representative of the underlying construct. This extracted composite factor score, accounting for 68.5% of the variance in the original scores, was used in the regression analyses.
A series of multiple linear regression analyses was performed to examine the amount of variance in reading comprehension accounted for by variables and/or factors (Table 5). Since improved speech perception is the main effect of cochlear implantation, both speech perception measures were entered in the first step. They accounted for 9.2% of the variance in reading comprehension. Next, educational placement was added, since this child-related factor was significantly correlated with reading comprehension. Together with the speech perception measures, 27.1% of the variance in reading comprehension was explained. The final step examined the degree of importance of the composite factor to reading comprehension. This factor accounted for 47.1% of added variance in reading comprehension. Together, all added variables accounted for 74.2% of the variance in reading comprehension, which reached significance (p = .000). Looking at the coefficients in the final step, only the composite factor contributed significantly to reading comprehension (p = .000). Thus, word knowledge, word reading skills at word level and verbal memory measures were not only highly related to one another, but played a major role in successful reading comprehension.

Insert Table 5 about here----------

Discussion

The main objective of the present study was to examine reading comprehension in Dutch school-aged children with prelingual severe to profound hearing loss who received CI before age 3, and the variance in their performance.
Results revealed that children who received CI before age 3 performed significantly better on reading comprehension compared to children in previous studies in Dutch-speaking children with CI[8,9], who received CI at an older age. The children in this study achieved, on average, (near) age-appropriate reading comprehension scores. Half of the children achieved reading comprehension scores within or above the normal range. Further analyses indicated that children in mainstream education outperformed children in DHH schools on reading

comprehension. 74,% of the variance in reading comprehension was explained by speech perception in challenging listening situations, educational placement, and a common factor, underlying word knowledge, reading skills at word level, and verbal WM.

The result, indicating better reading comprehension performance for children who received their CI before the age of 3, was expected, and in line with other studies[17,18,29]. As previously mentioned, early access to auditory information leads to a better phonological development[10,11], and a high rate of spoken language development after implantation[30], resulting in (near) age-appropriate language and reading outcomes[17–20,31]. In this study, all children achieved relatively good speech perception scores, and the distribution of these scores was small. Therefore, only weak associations were found between reading comprehension and speech perception in challenging listening situations. Both speech perception measures accounted for 9,2% of the variance in reading comprehension. In addition, children who received CI before the age of 18 months achieved slightly higher reading comprehension scores than children who received CI between 18 and 36 months, although not significant. Therefore, in this study reading comprehension was weakly associated with age at implantation.

The finding that children in mainstream education achieved significantly higher reading comprehension scores compared to children in DHH schools, is consistent with previous studies[15,31–34], which reported better language and reading outcomes, or overall school performance for children in mainstream education. Educational placement accounted for nearly 18% of the variance in reading comprehension. This result may be explained by the fact that most of the children attending DHH schools had additional problems, like behavior and/or neurological problems. In general, the presence of additional problems in children with CI is associated with poor language and reading outcomes[32,35], which could be partly explained by a linguistic deficiency or learning disability[34].

Due to the cross-sectional design of this study, it was not possible to demonstrate whether placement in mainstream education was the result, or the cause of good outcomes.

Children with bilateral CI in this study performed better on reading comprehension compared to children with unilateral CI, although not statistically significant. This trend was also found in the study of Sarant et al.[21]. Recent studies demonstrated the advantage of bilateral CI for speech perception[12,36,37], for language outcomes[15,36,38] and for verbal cognition[37]. Given these findings, a significant benefit of bilateral CI for reading comprehension might be found in a larger sample.

In line with the Simple View of Reading model[1], strong positive relationships were found between reading comprehension, word knowledge and reading skills at word level. More word knowledge, and better reading skills at word level, were associated with better reading comprehension. As previous studies have suggested[8,19], and as was also confirmed in the

present study, age-appropriate scores were obtained on both tests for reading skills at word level. However, the mean score for word knowledge was at the lower end of the normal range. According to the model, part of the differences in reading comprehension of children with CI and hearing children could therefore be explained by differences in linguistic comprehension.

In addition, verbal WM, important for language growth after cochlear implantation[39], was significantly related to reading comprehension, word knowledge, and reading skills at word level. These strong relationships suggested a common underlying process. The composite factor, extracted from these measures, accounted for 47% of the variance in reading comprehension performance. In reading, after decoding or recognizing words, they are temporarily stored in working memory, retrieving information from long-term memory to provide the meaning of what is read. In this study, the children achieved WM scores within the normal range of hearing children, while the STM was below the normal range. This is in contrast with findings of Harris et al[40], who reported that both STM, and WM performance of children with CI lie one SD below that of hearing children. This inconsistency may be explained by the fact that only 36% of the participants in their study received CI before the age of 3.

This study provided an update of the performance of Dutch children in reading comprehension since 2007, and confirmed the findings in international studies. The study sample was considered to be representative for the present population: mean age at implantation between 1 and 2 years of age, children with and without additional problems, the majority in mainstream education and half of the children with bilateral CI. However, a number of limitations have to be considered. For instance, the small sample size and the absence of a control group with hearing children. For one participant, no reading comprehension scores were available, while for another child the reading comprehension task was too difficult to administer. Secondly, not all tasks were standardized tests; therefore, no comparisons with hearing children from a norm sample could be made for these measures. Finally, because of the cross-sectional design of this study, no causal relationships could be established. For future research in reading comprehension in children with CI, it is suggested to design a longitudinal study with a larger group of children with CI, and a control group of hearing children, using standardized tests.

As mentioned in the introduction, reading comprehension is a complicated skill. Since word reading skills were adequate for most children in this study, word knowledge, as a measure of linguistic comprehension, appeared to be very important. While hearing children acquire many words and more common background knowledge by incidental learning, for children with CI incidental learning is not a matter of course. Therefore, parents of a child with CI, and professionals at home and at school, should create a rich linguistic environment from an

early age on. For instance, by sharing books as a routine, which should be continued in school-age, their word and background knowledge can be enlarged, and listening comprehension can be enhanced as a precursor for reading comprehension.

Conclusion

Overall, the results of this study indicate that many children who received their CI before age 3, and attending mainstream education, comprehend written texts more easily than ever before.

Given the current policy of bilateral cochlear implantation around the first birthday, children with CI who are provided with a rich linguistic environment from an early age on, will have good prospects for academic success.

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Tables

Table 1

Baseline characteristics of the participants (n=24)

		n	%
Gender	Male	16	67
	Female	8	33
Additional problems	Yes	7	29
	No	17	71
Communication mode at home	Oral language	19	79
	SSD	4	17
	SNL	1	4
Educational placement	Mainstream	15	63
	DHH	9	37
Contralateral stimulation	Yes, CI	10	42
	Yes, HA	2	8
	No	12	50
		Means (SD)	Range
Age at testing (mo.)		121 (17)	92 - 148
Age at first implantation (mo.)		19 (6)	11 - 31
Duration of CI use (mo.)		101 (17)	74 - 134
Age at second implantation (mo.) (n=10)		51 (35)	11 - 127

Note. SSD= Sign Supported Dutch; SLN= Sign Language of the Netherlands; CI= Cochlear implant; HA= Hearing Aid; SD.= standard deviation; DHH= schools for deaf and hard-of-hearing children; mo. = months; dB= decibel;

Table 2

Mean scores and standard deviations for reading comprehension, reading skills at word level, verbal memory, and speech perception measures for children with CI, and for hearing children in the norm sample (if available)

	Norm sample	Children with CI			
	Mean (SD)	N	Mean (SD)	Range	% ≥ NR
Reading comprehension	0 (1)	22	-0.8 (1.7)	-4.3 - 3.5	50.0
Word knowledge	100 (15)	23	87.7 (19.2)	55 - 130	65.2
Decoding	10 (3)	23	9.9 (2.6)	5 - 14	87.0
Word recognition	10 (3)	23	9.8 (2.6)	5 - 15	91.3
Word span	1.00 (0.18)	24	0.59 (0.16)	0.35 – 0.99	8.3
Digit span backwards	10 (3)	24	8.8 (2.9)	4 - 14	75.0
Non word repetition		24	77.4 (12.5)	40 - 94	
Speech perception in noise		23	62.0 (10.5)	45 - 84	
Speech perception 45 dB		22	82.9 (9.8)	63 - 97	

Note. CI= cochlear implant(s); SD=standard deviation; ≥ NR= percentage of CI group scoring within or above the normal range; dB= decibel;

Table 3

Spearman's rank correlations (one-tailed) between reading comprehension and child-related factors (n=22)

	Age at implantation before/ after 18 mo.	Educational placement	Additional problems	Uni-/ bilateral CI	Communication mode at home
Reading comprehension	-,216	-,478*	-,153	,258	-,094
Age at implantation before/after 18 mo.	-	,296	,222	-,083	-,146
Educational placement		-	,519**	,069	,290
Additional problems			-	-,036	,348*
Uni-/bilateral CI				-	,280

Note. mo.= months; CI= cochlear implant

**Correlation is significant at the 0.01 level (1-tailed)

* Correlation is significant at the 0.05 level (1-tailed)

Table 4

Spearman's rank correlations (one-tailed) between reading comprehension, word knowledge, reading skills at word level, verbal memory and speech perception measures (n=22)

task	word knowledge	decoding	word recognition	word span	non-word repetition	digit span backwards	speech perception 45 dB	speech perception in noise
reading comprehension	,621**	,522**	,632**	,244	,322	,592**	,123	,281
word knowledge	-	,533**	,822**	,301	,511**	,405*	,210	,314
decoding		-	,645**	,363*	,255	,378*	,036	-,015
word recognition			-	,299	,456*	,409*	,344	,343
word span				-	,389*	,393*	,052	,038
non-word repetition					-	,401*	-,191	,205
digit span backwards						-	-,045	-,042
speech perception 45 dB							-	,570**

**Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 5

Hierarchical multiple regression analyses explaining variance in reading comprehension (n=22)

		reading comprehension	
		ß coefficient	p
Step 1			
	Speech perception 45 dB	-.036	.472
	Speech perception in noise	.060	.206
	R^2 change	.092	
	R^2	.092	
Step 2			
	Speech perception 45 dB	-.053	.264
	Speech perception in noise	.034	.448
	Educational placement	-1.731	.065
	R^2 change	.179	
	R^2	.271	
Step 3			
	Speech perception 45 dB	-.045	.133
	Speech perception in noise	.023	.420
	Educational placement	-.032	.961
	Composite factor	1.480	.000
	R^2 change	.471*	
	R^2	.742	

Note. The composite factor was extracted from word knowledge, reading skills at word level, and verbal working memory measures.

* Significance change in R^2 (p=.000)

Figures

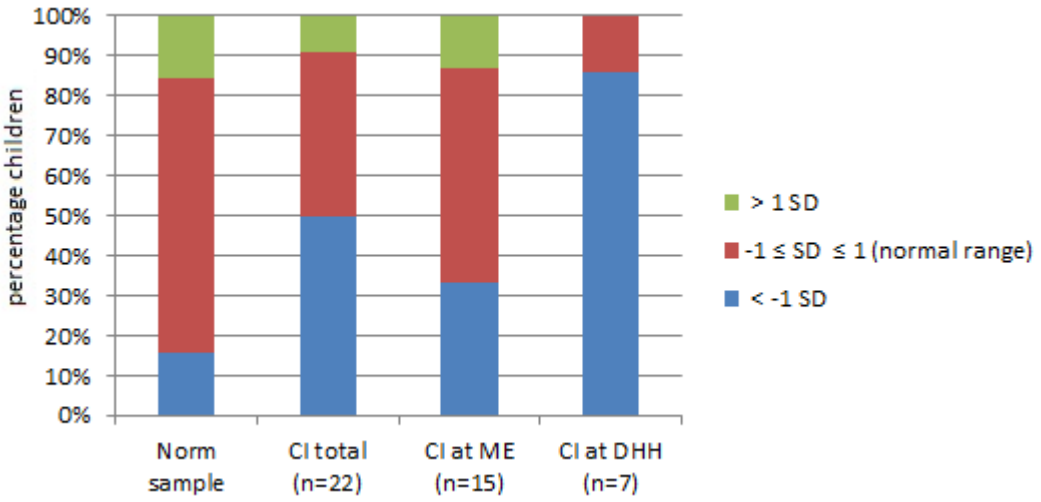

Figure 1. Distribution of reading comprehension scores for the norm sample, for the total group with CI, for the children with CI at mainstream education (ME), and for the children with CI at schools for deaf and hard-of-hearing children (DHH).

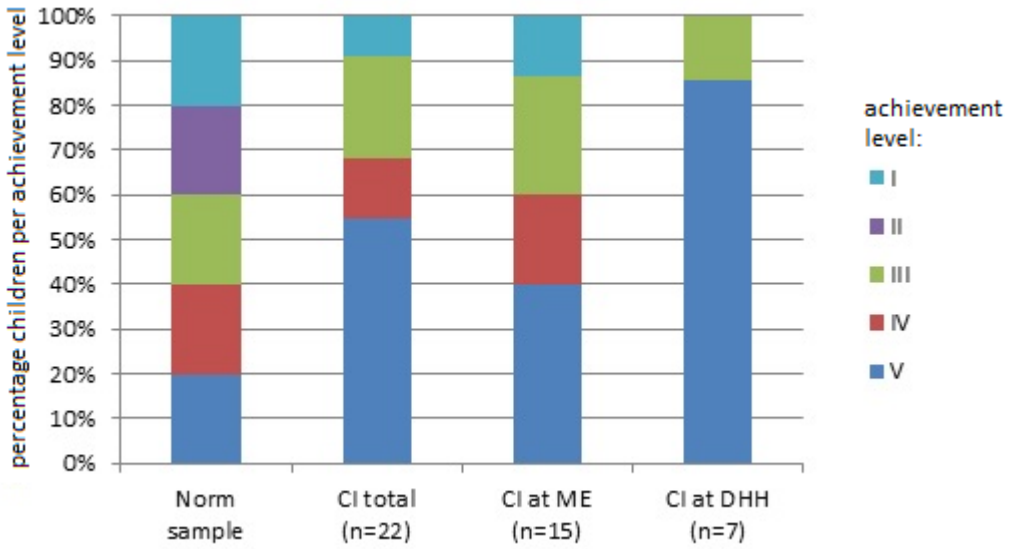

Figure 2. Distribution of reading comprehension scores per achievement level for the norm sample, for the total group with CI, for the children with CI at mainstream education (ME), and for the children with CI at schools for deaf and hard-of-hearing children (DHH).

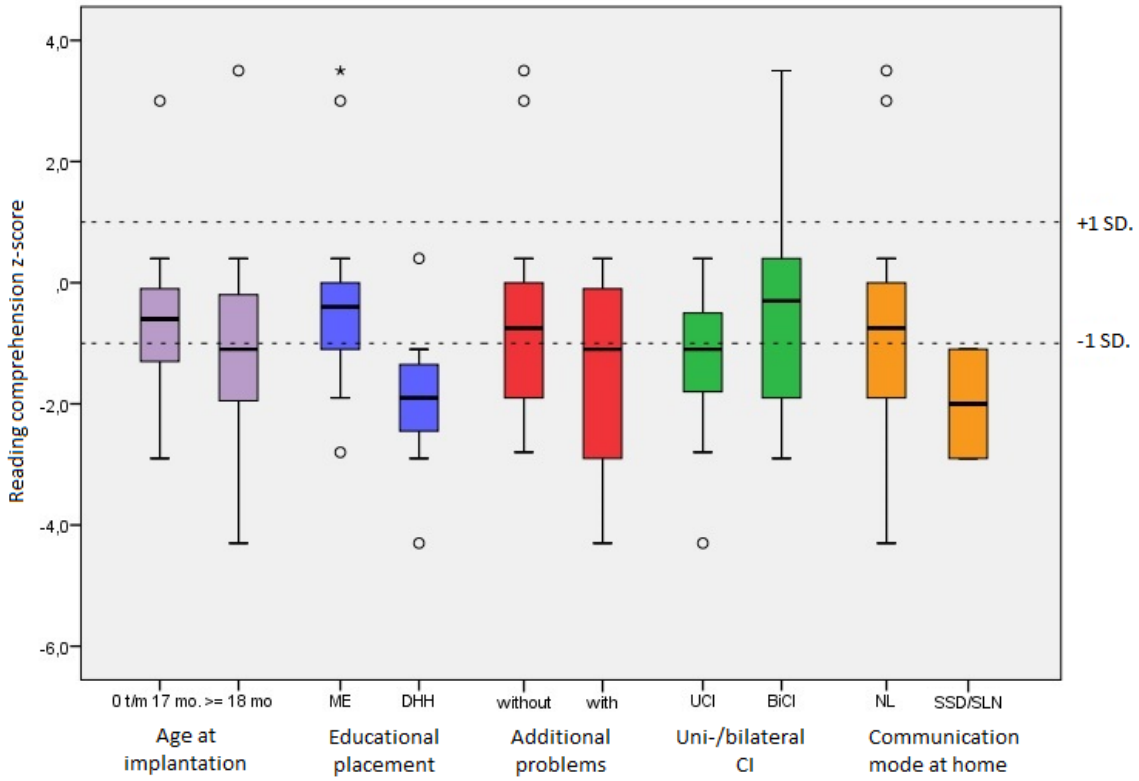

Figure 3. Boxplots with reading comprehension z-scores for subgroups: age at implantation before and after 18 months (purple), children in mainstream education (ME) and schools for deaf and hard-of hearing children (DHH) (blue), children with and without additional problems (red), children with uni- (UCI) and bilateral CI (BiCI) (green), and children using oral language (NL) or Sign Supported Dutch (SSD) or Sign Language of the Netherlands (SNL) at home (orange). The area between the dotted lines represents the normal range.

Dutch summary

Titel. Begrijpend lezen bij Nederlandse kinderen met een cochleaire implantaat.

Achtergrond. Begrijpend lezen is een belangrijke voorspeller voor schoolsucces. Eerder bleek dat dove kinderen met een cochleair implantaat (CI) beter presteren op het gebied van begrijpend lezen vergeleken met dove kinderen zonder CI, hoewel ze nog altijd een aanzienlijke achterstand hadden op horende leeftijdgenoten. Tegenwoordig krijgen kinderen hun CI op veel jongere leeftijd, met als resultaat verbeterd spraakverstaan en voor veel kinderen betere taalvaardigheden. De verwachting is daarom dat een aanzienlijk deel van deze kinderen leeftijdsadequate scores kunnen halen voor begrijpend lezen.

Doel. Onderzoeken van het begrijpend lezen bij Nederlandse kinderen met prelinguaal (zeer) ernstige gehoorverliezen, die een CI kregen voor hun 3^{e} jaar, en van de variatie in hun prestaties.

Methode. Begrijpend lezen werd onderzocht bij 24 kinderen tussen de 7 en 12 jaar, met een gemiddelde leeftijd bij implantatie van 1;07 jaar. De associaties met technisch lezen, woordkennis, verbaal geheugen, spraakverstaan en verschillende kind-gerelateerde factoren werden bepaald. Voor vergelijkingen met horende kinderen werd gebruik gemaakt van referentie gegevens van de normgroepen uit de gestandaardiseerde testen.

Resultaten. De helft van kinderen die hun CI kregen voor hun 3^{e} jaar, behaalden leeftijdsadequate scores op begrijpend lezen. Kinderen in het reguliere onderwijs presteerden significant beter dan kinderen op scholen voor dove en slechthorenden. 74% van de variatie in begrijpend lezen kon worden verklaard door spraakverstaan in moeilijke luistersituaties, schoolplaatsing en door een samengestelde factor, geëxtraheerd uit scores op technisch lezen, woordkennis en verbaal werkgeheugen.

Conclusie. Veel kinderen die een CI krijgen voor hun 3^{e} jaar en in het reguliere onderwijs zitten, behaalden scores voor begrijpend lezen die vergelijkbaar zijn met die van hun horende klasgenoten. Aangezien begrijpend lezen belangrijk is voor schoolsucces, zijn de vooruitzichten veelbelovend voor de huidige populatie kinderen met CI.

Abstract

Title. Reading comprehension in Dutch school-aged children with cochlear implants.

Background. Reading comprehension is an important predictor of school performance. Although previous studies reported better reading comprehension for children with cochlear implants (CI) compared with deaf children without CI, their performance was still lagging behind that of hearing children. Today children receive CI at a much younger age, which is associated with improved speech perception, and enhanced spoken language development. Therefore, it is hypothesized that for a substantial part age-appropriate reading comprehension scores are feasible.

Aim. To examine reading comprehension in Dutch school-aged children with prelingual severe to profound hearing loss who received CI before the age of 3, and the variance in their performance.

Methods. Reading comprehension was assessed in twenty-four children with CI, aged 7 to 12 years, with a mean age at implantation of 1;07 years. Associations with reading skills at word level, word knowledge, verbal memory, speech perception in challenging listening situations, and with several child-related factors were examined. For comparisons with hearing children, reference data from the norm samples of the standardized tests were used.

Results. Half of the children, who received CI before the age of 3, achieved age-appropriate reading comprehension scores. Children in mainstream education performed significant better than children in schools for deaf and hard-of-hearing children. 74% of the variance in reading comprehension could be explained by speech perception in challenging listening situations, educational placement, and a composite factor, extracted from reading skills at word level, word knowledge and verbal working memory.

Conclusion. Many children who received CI before age 3, attending mainstream education, achieved reading comprehension scores similar to their hearing peers. Since reading comprehension is important for overall academic success, the prospects for the present population of children with CI are promising.

Keywords. Cochlear implants, child, reading, language [MESH].

Appendix. Word span - items

practice 1	boom – vis
practice 2	deur – mes
item 1	voet – hek
item 2	kam – boom – peer
item 3	huis – pijp – peer
item 4	vis – hek – kam
item 5	pijp – voet – huis
item 6	mes – kam – peer – boom
item 7	hek – deur – vis – pijp
item 8	peer – huis – mes – voet
item 9	deur – boom – kam – hek
item 10	pijp – vis – mes – huis – voet
item 11	hek – peer – boom – deur – kam
item 12	voet – pijp – huis – vis – mes
item 13	boom – kam – peer – hek – deur – pijp
item 14	vis – voet – deur – huis – kam – mes
item 15	huis – hek – pijp – peer – boom – voet