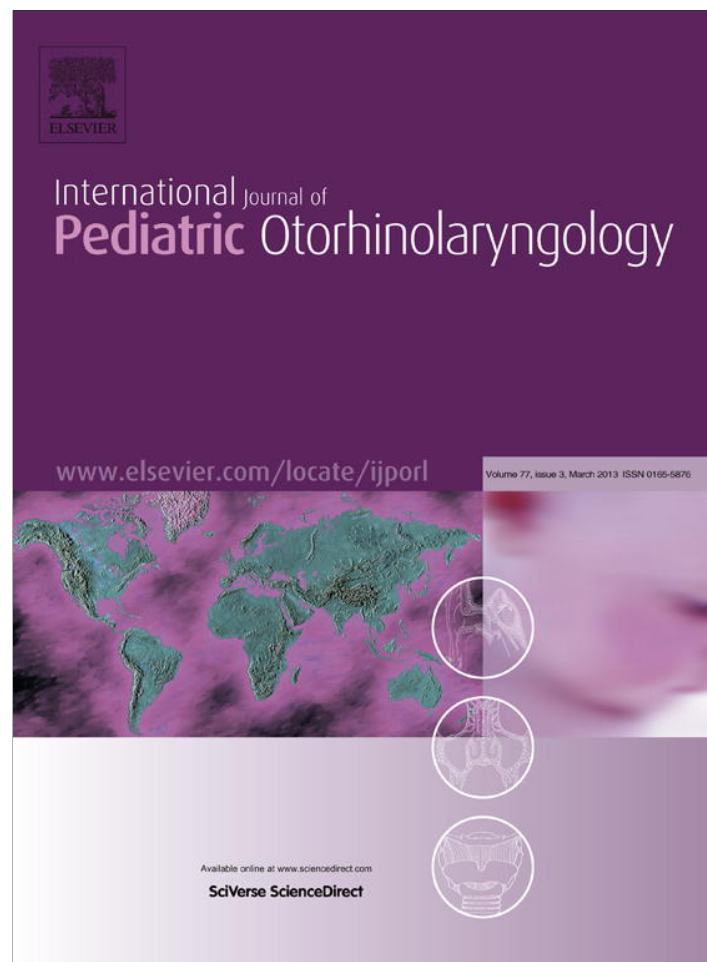


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Infrequent word classes in the speech of two- to seven-year-old children with cochlear implants and their normally hearing peers: A longitudinal study of adjective use

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ABSTRACT

Objective: Studies investigating language skills of children after cochlear implantation usually use global language proficiency scores and rarely tackle the acquisition of specific language phenomena (word classes, grammatical constructions, etc.). Furthermore, research is largely restricted to frequent word classes (nouns, verbs). The present study targets the acquisition of adjectives (e.g. *big*, *intelligent*) by children implanted before their second birthday. Adjectives constitute a relatively infrequent, but functionally important word class and were shown to be good indicators of language delays and impairments.

Method: Nine cochlear-implanted (CI) children and 60 age-matched normally hearing (NH) controls participated in the study. The CI children were followed longitudinally from ages 2 to 7; control data were collected in a cross-sectional manner (10 children per age group). Samples of children's spontaneous interactions with their caregivers were transcribed and analyzed for adjective use (frequency, lexical diversity, complexity of syntactic constructions, and morphological correctness).

Results: The performance of the CI subjects was not significantly different from that of NH peers on adjective frequency and lexical diversity. On these measures, both groups reached adult levels by age 3. However, the CI group had a significant delay in the acquisition of complex syntactic constructions. The NH subjects produced adjectives in adult-like grammatical constructions from age 3 onwards, whereas their CI peers lagged behind until age 5. The speech of the CI participants also featured morphological errors that are not characteristic of typical development (inflection of predicative adjectives). However, the overall error rate was low.

Conclusions: The findings suggest that CI children have particular difficulty with grammatical items (bound morphemes, copulas) that are less salient in the flow of speech than content words. Nevertheless, children implanted before their second birthday are able to catch up with their hearing peers by age 5, even in the use of relatively infrequent word classes.

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1. Introduction

1.1. Language development after cochlear implantation

The advent of cochlear implantation made it possible for deaf children to develop speech and language skills that often surpass those of children using hearing aids [1,2]. It is, however, not surprising that cochlear-implanted (CI) children often display significant delays in the acquisition of both vocabulary [3–8] and grammar [9–13] compared to their normally hearing (NH) peers. Complex syntax appears to be more demanding for CI children

than lexical diversity [13–16]. The acquisition of spoken language grammar by CI users was shown to be significantly delayed, especially in the domain of bound morphemes and function words, such as determiners, copulas and modal verbs [7,9,13,14]. These elements are less stressed and, therefore, less easily identifiable for children with a hearing impairment. As a result, CI children tend to produce less complex syntactic structures and often fail to mark syntactic relations [12].

Most studies thus far have presented a very broad picture of language development in the CI population, presenting general measures of expressive/receptive vocabulary and grammar [1,15,17–23]. There have been relatively few attempts to trace the development of specific language phenomena, such as the acquisition of noun [7,9,12,13] and verb morphology [9,13,24,25]. Notice that nouns and verbs are the most frequent lexical

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categories in parental input [26]. Hardly any research has so far targeted the acquisition of less frequent lexical categories, such as adjectives and adverbs, by children with cochlear implants. Le Normand et al. [27] examined the frequencies of words from 36 lexical categories in the longitudinal speech samples of 17 French-speaking CI children implanted between 22 and 76 months of age. They found that three years post implantation the frequencies of adjectives, determiners, nouns, lexical verbs and auxiliaries in the speech of CI children were not significantly different from the distributions in the control group matched for MLU. However, significant differences between the two groups were found on negation adverbs, place adverbs, communicators, possessives, prepositions and pronouns, as well as on infinitive, modal and existence verbs.

1.2. The acquisition of adjectives by hearing-impaired children

In this study, we focus on the development of the adjective category in the speech of CI children. Although adjectives constitute a third most important content word class after nouns and verbs, their acquisition by CI users has barely been investigated. The only exception is Herzberg's study [9] that compared the production of nouns, verbs and adjectives by Hebrew-speaking children with cochlear implants. In this paper, we target adjective production in spontaneous speech of CI children acquiring Dutch.

Adjectives are not a universal category, as some languages map properties to nouns and some to verbs [28,29]. Dutch adjectives constitute an open word class denoting various properties of objects, people and events (e.g. *rood* 'red', *droog* 'dry', *intelligent* 'intelligent'). Syntactically, adjectives are dependent on nouns, as indicated by the two syntactic positions they typically occupy in the world's languages – predicatives (e.g. *Jack is smart*) and attributives (e.g. *a smart boy*) [30,31]. In many languages adjectives agree with head nouns in inflectional properties (number, gender, case, and definiteness), particularly as modifiers within a noun-phrase. For example, the Dutch adjective *klein* 'small' is inflected with *-e* when modifying plural nouns (e.g. *kleine huizen* 'small houses'), singular nouns of common gender (e.g. *een/de kleine muis* 'a/the small mouse') and definite nouns of neuter gender (e.g. *het kleine paard* 'the small horse'). Agreement inflections, like other bounded morphemes, are unstressed and, therefore, less easily identifiable in the flow of speech. Hence, their acquisition might be problematic for children with a hearing impairment. Furthermore, even in typical language development adjectives were shown to be acquired relatively late because they are conceptually complex [32]. In order to understand what an adjective such as *red* means, children need to be able to attend selectively to one particular dimension such as colour [33] and to determine which of a whole range of attributes displayed by the object is meant [34]. Furthermore, adjectives are relatively infrequent compared to nouns and verbs. Naturalistic studies of

spontaneous speech show that adjectives account for only about 5% of word tokens in child-directed speech [27,35]. Therefore, it is not surprising that adjective production was shown to be a good indicator of language proficiency [36] and language impairments [37–39].

For hearing-impaired children, evidence in the literature is scarce and somewhat controversial. Heward and Eachus [40] found that school-age children with a hearing impairment avoid using adjectives and adverbs in their writing. As against this, Herzberg [9] reports that Hebrew-speaking CI children use more adjective tokens than NH children matched for chronological age. However, adjectives in the speech of CI patients appear to be less diverse and used in a more restricted range of syntactic environments compared to adjective production by NH controls. In order to determine to what extent these results can be generalized to other languages, more research is clearly warranted. It is also important to target other aspects of adjective production, such as complexity of syntactic frames in which adjectives are used and the acquisition of adjective agreement morphology.

The study reported in this paper will compare the use of adjectives in the longitudinal transcripts of nine CI children acquiring Dutch with adjective production by NH children matched for chronological age. The following aspects of adjective use will be addressed: frequency, lexical diversity, complexity of syntactic frames and morphological correctness. Another goal of this investigation is to compare the patterns in child speech to distributions in the parental input.

2. Method

2.1. Subjects

In this study, we used a longitudinal corpus of nine CI children, all monolingual speakers of Belgian Dutch. The children were about 2 years of age at the outset of the study and 7 years of age at the end of the data collection, with the exception of two participants who left the study earlier (S2 at age 6 and S9 at age 5). All of them received a Nucleus 24 cochlear implant before their second birthday. The data were collected longitudinally around the children's birthdays. More detailed information on each subject is presented in Table 1.

At each datapoint, the performance of CI participants was compared to that of NH peers matched for chronological age. The control data were collected in a cross-sectional manner (10 by age group). All participants were native speakers of Belgian Dutch, with no patent cognitive or health deficits. Six comparison groups were included in the study: ten 2-year-olds (age range: 1;11–2;3, mean age: 2;1), ten 3-year-olds (age range: 2;10–3;2, mean age: 3;0), ten 4-year-olds (age range: 3;10–4;3, mean age: 4;0), ten 5-year-olds (age range: 4;11–5;3, mean age: 5;1), ten 6-year-olds (age range: 5;10–6;3, mean age: 6;1) and ten 7-year-olds (age

Table 1
Individual child characteristics of the CI group.

ID	Gender	Age at implantation first CI	Age at implantation second CI	Unaided hearing loss	Aided hearing loss	Age at first recording	Age at last recording
S1	F	1;01.15	6;03	120	38	2;01.01	7;01.09
S2	F	0;06.21	4;08	120	30	1;11.24	6;00.15
S3	F	0;10.00	5;10	115	25	1;11.22	7;00.27
S4	M	1;06.05	–	113	25	1;11.23	7;01.14
S5	M	1;04.27	6;04	93	35	2;00.25	7;00.18
S6	M	0;08.23	–	120	38	1;11.25	7;02.08
S7	F	0;05.05	1;03	117	23	2;00.06	7;00.19
S8	F	1;07.14	–	112	55	1;11.23	7;00.07
S9	F	0;08.21	1;11	103	42	1;11.22	5;00.07

range: 6;10–7;2, mean age: 7;0). As in the CI group, data were collected around the children's birthdays.

2.2. Data collection and transcription

Spontaneous parent–child interactions were video-recorded in unstructured home settings. For each recording, a sample of 20 min was independently transcribed by two researchers and a consensus transcription was derived. The transcribers were equally experienced and participated in research projects that did not aim at studying adjective use. All transcriptions were made using the CHILDES CHAT transcription format [41]. The transcriptions were tagged with CHILDES MOR software tool producing lemmatization and part-of-speech tagging, which allowed automatic counting of adjective tokens and lemmas, as well as automatic extraction of all adjectives for further coding.

The resulting tags were manually verified by the first author. Hereby we applied the criteria developed for the part-of-speech tagging of the Spoken Dutch Corpus [42]. A word was selected as an adjective if it satisfied the following criteria [28–31]: (a) being an open-class word, thus excluding pronouns, determiners, etc.; (b) having adjectival semantics, i.e. denoting properties, attributes or states of noun referents (thus, excluding actions, objects, etc.); (c) having adjectival inflectional morphology; (d) being used in adjectival syntactic positions (attributive, predicative, adverbial, and (post)nominal).

If a word that can be both an adjective and a noun (e.g. *blauw* 'blue') was used outside a syntactic context, i.e. in a single-word utterance, its contextual interpretation (and thus inclusion in the adjective category) was determined on the basis of the contextual cues from the preceding utterances. Adjectives that are formally not distinguishable from adverbs were coded as (adverbially used) adjectives if the same word can also be used in the attributive position with the same meaning (e.g. *Peter rijdt snel* 'Peter drives fast', cf. *een snelle rijder* 'a fast driver'). Adjectival particles constituting parts of separable verbs such as *opendoen* 'open' (lit. make open) were not coded as adjectives. Participles were only included in the analysis if they had the following adjectival properties: a. adjectival prefix (e.g. *ongehoord* 'unheard-of'); b. adjectival inflection (e.g. *opgewekter* 'livelier', *iets spannends* 'something exciting') [42].

2.3. Sample normalization

In order to take into account differences in volubility between the children, a bootstrapping procedure was implemented [43]. From each transcription a subset of 100 word tokens was randomly selected and this selection was repeated 5151 times (the binomial coefficient reveals that for a set of 102 items 5151 unique permutations are possible). For the token counts, the number of adjective tokens was tallied in each of the 5151 unique random samples, and the median number of tokens was used in the statistical analyses. For the type counts, the same bootstrapping procedure was implemented, but now the number of different adjective lemmas was computed in each random sample. The median number of adjective lemmas was used in the statistical analyses.

2.4. Coding

Each adjective occurrence (token) in child speech (CS) and child-directed speech (CDS) was coded as either non-syntactic or syntactic. An adjective was coded as non-syntactic, if it was used in a single-word utterance (*Heet!* 'hot') or in a telegraphic phrase (*Jan moe* 'Jan tired'). Adjectives used in full syntactic constructions

– predicative (*De bal is rood* 'The ball is red'), attributive (*een rode bal* 'a red ball'), adverbial (e.g. *Hij rijdt snel* 'He drives fast') or (post)nominal (e.g. *iets interessants* 'something interesting') – were coded as syntactic.

We also coded for correctness of the morphological form. Apart from the *-s* inflection in postnominal constructions, Dutch adjectives are only inflected with *-e* in the attributive position, as in *een grote olifant* 'a big elephant'. However, when the modified noun is indefinite, singular and neuter, the adjective is not inflected, as in *een groot huis* 'a big house'. If an adjective modifies a singular neuter noun, which is definite, both the *-e* inflection (e.g. *het grote huis* 'the big house') and the zero inflection (*het groot huis* 'the big house') are possible in Belgian Dutch.

In total, we coded 1118 adjectives in the speech of the CI children and 2183 adjectives in the input to them. The number of analyzed adjectives in the speech of NH children was 1031, and in the parental input to these children – 1969.

Ten percent of the data were re-coded approximately ten months after the final coding. The intra-coder agreement was 100% for the CI corpus and 98.2% for the NH corpus.

2.5. Analysis

The data of the CI children are fully longitudinal: each child was recorded at consecutive points in time. The data of the NH children are cross-sectional, meaning that each child was recorded only once. A multilevel model is in operation. The data of the CI children consist of three hierarchically clustered samples: children (Level 3), within children samples were drawn at consecutive ages (Level 2), and at each occasion the bootstrapping procedure results in 5151 frequency counts (Level 1). The data of the NH children exhibit only two levels since each child was only recorded once and not at multiple occasions.

3. Results

3.1. Frequency of adjective use

Estimated probability of adjective occurrence in the speech of CI and NH children is presented in Fig. 1.

Between 2 and 3 years of age there is a significant increase in adjective use in the CI group ($\chi^2(1) = 4.04, p = 0.04$) and in the NH group ($\chi^2(1) = 8.21, p = 0.004$). From age 3 onwards, adjective use remains stable in both groups. No significant differences between the two groups of children were found (all p values above 0.05). CI children use adjectives as often as their NH peers do. However, as shown in Fig. 1, there is a lot of individual variability in the probability of adjective occurrence.

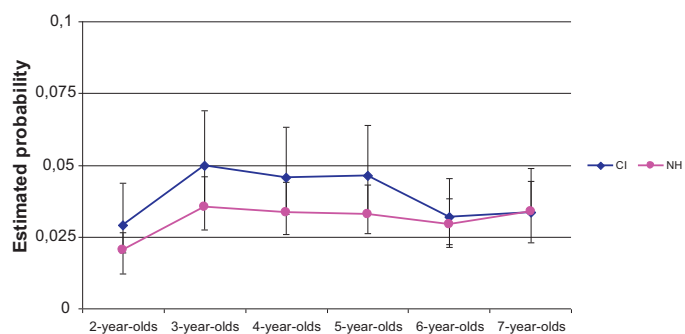


Fig. 1. Estimated probability of adjective occurrence by age and hearing group (error bars indicate 95% confidence intervals).

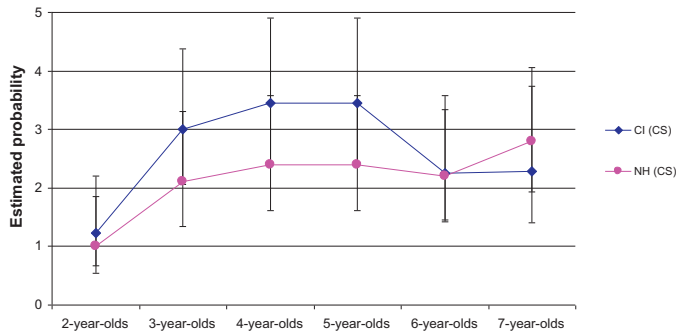


Fig. 2. Estimated adjective diversity by age and hearing group (error bars indicate 95% confidence intervals).

3.2. Lexical diversity

In order to assess lexical diversity of the children's adjective lexicons, we measured the number of different adjective lemmas used in random samples of 100 words. Different morphological forms of the same adjective (e.g. *groot* 'big' and *groter* 'bigger') were counted as one lemma. Fig. 2 summarizes estimated lemma frequencies by age and hearing group.

As in the case of token frequencies, there is a significant increase in the diversity of the adjective lexicons between ages 2 and 3. This was the case for the CI group ($\chi^2(1) = 6.3, p = 0.01$) and for the NH group ($\chi^2(1) = 3.7, p = 0.05$). No significant differences between the two groups of participants were found (all p values above 0.05).

3.3. Syntactic complexity

The estimated proportion of adjectives used in full syntactic structures by children and their caregivers is presented by age group and hearing group in Fig. 3.

Caregivers use adjectives primarily in full syntactic constructions; only 10% of all adjectives in the CDS are used in single-word utterances and telegraphic phrases. Input to CI children is in this respect not different from input to NH children across all ages studied (all p values above 0.05). Both child groups start using adjectives primarily in non-syntactic contexts. At age 2, the performance of the CI group is not significantly different from the NH group: $p = 0.83$. At the same time, both child groups use adjectives in full syntactic frames significantly less frequently than their caregivers: $\chi^2(1) = 12.01, p < 0.001$ (CI), $\chi^2(1) = 24.01, p < 0.001$ (NH). Syntactic complexity of adjectives in the NH corpus shows a rapid development between ages 2 and 3. From age 3 onwards, the percentage of adjectives used in full syntactic frames in the speech of NH children is not different from the CDS (all p values above 0.05). Syntactic development in the CI group

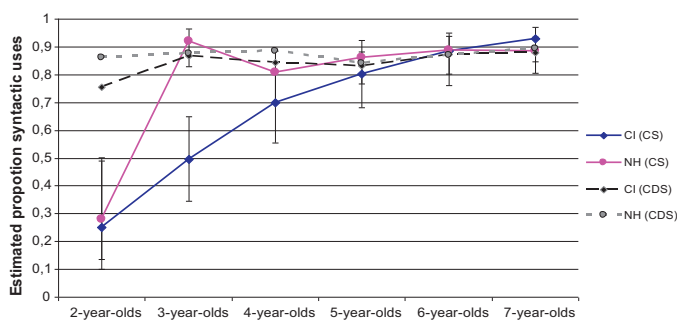


Fig. 3. Estimated proportion of adjectives used in full syntactic constructions (error bars indicate 95% confidence intervals).

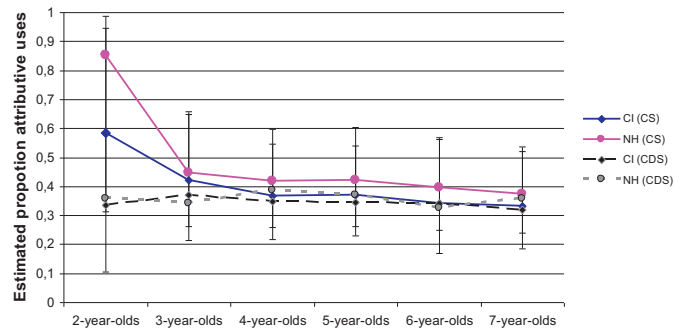


Fig. 4. Estimated proportion of syntactic adjectives used attributively (error bars indicate 95% confidence intervals).

proceeds more slowly. At age 3 CI children still use fewer full adjectival constructions than their caregivers, $\chi^2(1) = 19.5, p < 0.001$, and than the NH controls, $\chi^2(1) = 20.3, p < 0.001$. At age 4 the proportion of syntactically used adjectives in the speech of the CI children is still marginally lower than in the CDS, $\chi^2(1) = 3.8, p = 0.05$, but no longer significantly different from the CS in the NH corpus ($p = 0.16$). From age 5 onwards, CI children use adjectives in full syntactic constructions as often as their parents and their NH peers (all p values above 0.05). Finally, it should be mentioned that across all age groups, but especially at younger ages, there are larger differences between individual children in the CI group than in the NH group.

For the adjectives used in full syntactic frames we further compared the proportion of attributive (e.g. *red ball*) vs. predicative (e.g. *ball is red*) uses; see Figs. 4 and 5 respectively. The frequencies of adjectives used in other syntactic frames (adverbial, nominal, postnominal) are too low to allow comparisons.

Overall, the distribution of adjectives across syntactic constructions in the CS is very similar to the CDS. Only 2-year-old NH children use marginally more attributive adjectives than their parents, $\chi^2(1) = 2.95, p = 0.08$. The same tendency is observed in the CI corpus, but the difference between CS and CDS is not significant ($p = 0.4$). No other significant differences between the groups were found. Yet again, we observe large individual differences between the children; these differences become smaller with age.

3.4. Morphological correctness

Children in both groups make very few inflection errors. An average error rate in the CI group is 4% and in the NH group 3%. However, a qualitative error analysis reveals a remarkable difference between NH and CI children. The majority of inflection errors in the NH group are agreement errors in the attributive

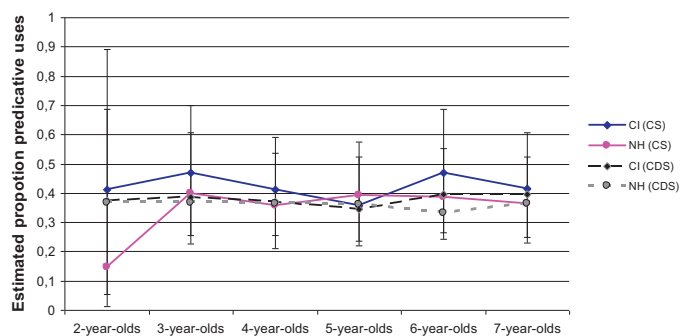


Fig. 5. Estimated proportion of syntactic adjectives used predicatively (error bars indicate 95% confidence intervals).

phrases. In about half of the cases the children over-generalize the *-e* inflection to singular neuter noun-phrases (e.g. *#kleine kalfje* instead of *klein kalfje* 'small calf'). In the other half of the cases, they erroneously leave an attributive adjective uninflected (e.g. *klein beestjes* instead of *kleine beestjes* 'small creatures'). These errors are also common in the CI group. However, only the CI subjects make inflection errors by adding the *-e* inflection to predicative adjectives, as in *Die was kleine* 'That (one) was small'. Such errors account for 17% of all adjective agreement errors found in the CI corpus and were even attested in the speech of the oldest CI children in our sample.

4. Discussion

Taking as a starting point the assumption that adjective production is a good indicator of a delay in the linguistic development [38,39], the present study set out to explore the development of adjective use in spontaneous speech of Dutch-speaking CI children compared to their NH peers. Adjective use was operationalized as overall token frequencies, lexical diversity, complexity of syntactic frames in which adjectives are used, as well as correctness of agreement inflection. The patterns in child speech were compared to the distributions in the parental input.

The results demonstrate that both child groups show a significant increase in adjective frequencies between 2 and 3 years of age; after that age adjective use remains relatively stable. Across all age groups, adjective frequencies in the speech of the CI children were not significantly different from the frequencies in the speech of the NH children matched for chronological age. This finding is consonant with earlier research on adjective use by Hebrew-speaking CI users [9]. Furthermore, the diversity of the productive adjective vocabulary was also largely comparable between the two groups. This result diverges from the pattern reported by Le Normand et al. [27], where the number of adjectives produced by French-speaking CI children two years post implantation was significantly lower than in the speech of children matched for MLU. This divergence is presumably related to the differences in the ages of implantation. The subjects in the Le Normand et al.'s study were implanted between 22 and 76 months of age, whereas the subjects in the present study received cochlear implants much earlier, between 6 and 19 months of age. The results of this investigation are, therefore, consistent with prior research demonstrating that children implanted before two years of age have more chance to acquire language and speech skills that are commensurate with their age-matched peers without hearing loss [1,3,10,17,20–22].

However, we also found evidence of delay in the acquisition of the adjective category by the CI group. This delay is manifested in the complexity of syntactic constructions. The NH subjects reached the adult-like proportions of adjectives used in full syntactic frames by age 3, whereas the CI group lagged behind until age 5. This said, within the syntactic uses distributions of attributives and predicatives in child speech (both CI and NH) were by and large similar to the patterns in the input language.

Another result of interest is that only the CI children in this study over-generalized the agreement inflection to predicative adjectives. Predicative adjectives never take an agreement inflection in Dutch. Prior research on the acquisition of the Dutch adjective morphology shows that typically developing children never over-extend the agreement inflection to predicative adjectives [44–46]. This is in line with the pattern observed in our NH corpus. Therefore, the fact that CI children over-extend the agreement inflection to predicatives constitutes a remarkable deviation from the typical development of adjective morphology. This notwithstanding, it should be mentioned that the overall error rate in the CI corpus was very low.

All in all, the results of the present study indicate that after a period of initial delay CI children are able to catch up with their NH peers on all measures of adjective production, including lexical diversity, syntactic complexity and morphological correctness. In view of the hearing deficit, it is perfectly explicable that the CI subjects in this study had more difficulty acquiring morphosyntactic aspects of adjective use. Adjectives as such are content words that are stressed and, therefore, prominent enough in the flow of speech. Therefore, token and lemma frequencies of adjectives in the speech of CI children are very similar to those found in the NH corpus. In contrast, function words – determiners (e.g. *een ronde bal* 'a round ball') and copulas (e.g. *De bal is rond* 'The ball is round') – needed to construct full syntactic structures (attributive and predicative, respectively), as well as bound morphemes needed for adjective agreement (e.g. *ronde bal* 'round ball') are less stressed in the flow of speech. Since these elements are of low perceptual salience, it is not surprising that they appear to be particularly demanding for hearing-impaired children [cf. 9,13–15].

Another observation repeatedly made in this study is that there is a lot of individual variation in the performance of the CI subjects. This finding also concurs with a previous body of research recurrently indicating that some of the CI children perform within normal ranges, whereas others display a more profound delay [8,11–16,20,21,23].

5. Conclusion

This study demonstrated that adjective production in the spontaneous speech of hearing-impaired children that received a cochlear implant before 2 years of age is largely comparable to the patterns found in the speech of normally hearing age-mates. Morphosyntactic aspects of adjective use are the most demanding for cochlear-implanted children, which can be explained by low perceptual salience of the linguistic elements needed to construct full syntactic structures and to realize agreement. By the age of 5 years, adjective use in spontaneous speech of cochlear-implanted children is very similar to the patterns found in the speech of their caregivers and normally hearing peers.

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