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Noun plural production in preschoolers with early cochlear implantation: An experimental study of Dutch and German

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ABSTRACT

Objectives: Studies investigating language skills of children after cochlear implantation usually present general measures of expressive/receptive vocabulary and grammar and rarely tackle the acquisition of specific language phenomena (word classes, grammatical constructions, word forms, etc.). Furthermore, research is largely restricted to children acquiring English. Cross-linguistic comparisons among children acquiring different languages are almost inexistent. The present study targets the acquisition of noun plurals (e.g., *dogs*, *balls*) by Dutch- and German-speaking children implanted before their second birthday. Given its structural complexity and irregularity, noun plural formation is a good indicator of grammatical proficiency in children at risk for a developmental delay.
Methods: The study sample consisted of 14 cochlear-implanted (CI) children ($M = 55$ months of age), 80 age-matched normally hearing (NH) controls, and 40 normally hearing controls matched by Hearing Age (HA). The children were administered an elicitation task in which they had to provide plural forms to a set of singular nouns. The analysis focussed on the following variables: Hearing status (CI, NH), Language (Dutch, German), and Suffix Predictability/Stem Transparency of the plural words.
Results: There was no significant difference between children with CI and their NH peers in correct plural production. In both child groups, plural responses followed the predicted pattern of Suffix Predictability/Stem Transparency. However, children with CI significantly more frequently replied to the test item with a recast of the singular noun instead of the plural, and the probability of these responses increased with later age of CI implantation. Furthermore, Dutch-speaking children showed an overall better performance than German-speaking children.
Conclusions: The findings suggest that after 3 years of implant use, preschoolers with early cochlear implantation show age-appropriate patterns of noun plural formation, but still have to catch up with respect to associating a particular singular with its plural form.

1. Introduction

1.1. Language development after cochlear implantation

Nowadays, many profoundly deaf children are given access to auditory information by means of a cochlear implant (CI). Thanks to this device, these children are able to develop speech and language skills that often surpass those of children using hearing aids [1–3]. It is, however, not surprising that cochlear implanted children often display significant delays in the acquisition of both vocabulary and grammar, as compared to their normally hearing (NH) peers [4–6]. The acquisition of spoken language grammar by children with CI was shown to be significantly delayed, especially in the domain of bound morphemes and function words, such as determiners, copulas, and modal verbs [7–12]. These elements are often/mostly unstressed, perceptually less salient, and hence, less easily identifiable for children with a hearing impairment.

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 [3,13–17]. There have been relatively few attempts to trace the development of specific language phenomena, such as the acquisition of noun, verb, or adjective morphology [7,8,18–20]. Moreover, most published results on children with CI include English-speaking children and may not be directly applicable to

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deaf children who are acquiring other languages. Cross-linguistic comparisons among children with CI acquiring different languages are almost non-existent.

Another point of interest concerns the impact of Age-At-Implantation on children's speech and language skills. Early implantation results in a shorter period of sound deprivation and, thus, a longer auditory experience. Studies have demonstrated that children who received a CI by 24 months made better linguistic progress than children who were implanted thereafter [21–24]. Moreover, there has been found evidence that further improvement may come from implantation in the first year of life [25]. Another observation repeatedly made in the literature is that there exists high inter-individual variability in the performance of children with CI [5,17,21,26].

1.2. The acquisition of noun plurals by children with CI

In this study, we focus on the category of noun plurals in the speech of children with CI. Plural is a basic morphological category that emerges early on in child language [27–30]. It plays a central role in the morphology of noun phrases and as a trigger for grammatical agreement. It has a large cross-linguistic distribution, including sign languages [31], yet often exhibits much structural complexity and irregularity [32]. Therefore, across different languages, gaining command of the full complexity of noun plurals is a protracted developmental process that may continue across the school years [33–37].

For children with CI, evidence on morphological acquisition (and on noun plurals in particular) in the literature is scarce and somewhat contradictory. Svirsky et al. [7] administered three morphological tasks to English-speaking children with CI, focusing on noun plurals, copulas, and regular past tense [38]. The authors found that success rates in the CI group were highest for the copula, followed by the noun plural, and lowest for the regular past tense. By contrast, the NH control groups showed greater proficiency in the use of noun plurals than in the copula. This difference was explained by differences in perceptual salience of the respective grammatical cues (i.e., acoustically more salient copula "is" or "are" vs. less salient word-final sibilant/s/or/z/as in the plural "doll-s"). Against this, Szagun [8,18] found no difference between German-speaking children with CI and NH children in the correct production of noun plurals in a corpus of spontaneous speech. There was also no difference with respect to the type of plural errors produced by the children, with the only exception of erroneous zero plural marking (e.g., *die *Nashorn* instead of *die Nashörner* "the-PL rhinos") being more frequent in the CI group.

The two studies, however, differ in several respects: Firstly, the study by Svirsky et al. focussed on children acquiring English, while the study by Szagun investigated German-speaking children. Previous research on speech and language skills in normally hearing children has shown that children are from very early on sensitive to the "typological imperatives" of the language they learn [39,40]. This means that every language poses its specific problems for a language-learning child and hence conclusions reached from one language cannot be directly translated into another one. Secondly, Svirsky et al. used experimental elicitation, whereas Szagun used spontaneous speech sampling. Children's performance in a plural elicitation task may be different to spontaneous speech, due to differences in task demands between the two production methods [41]. Thirdly, Svirsky et al. interpreted noun plurals relatively to two other grammatical categories, while Szagun presented results for noun plurals separately. Hence, differences between the two studies may come from any single one or from a combination of these factors, and it is difficult to assess to what extent these differences are due to structural differences between languages. This would require a direct comparison between languages. The present paper aims at illuminating the role of cross-linguistic differences in grammatical complexity for the acquisition of noun plurals by children with CI by studying a particular morphological phenomenon in two different languages using the same methodology.

1.3. Suffix Predictability and Stem Transparency in plural formation

In this paper, we target noun plural production in Dutch- and German-speaking preschoolers with CI, using an experimental plural elicitation task. We focus on two characteristics of plural formation that were shown to be good indicators of grammatical proficiency in normally hearing children acquiring Dutch and German [42,43]: Suffix Predictability (i.e., how predictable is the plural suffix given the word-final phonology and gender?) and Stem Transparency (i.e., does the phonological make-up of the noun change when pluralized?).

As to Suffix Predictability, Dutch plurals consist of basically two phonologically unrelated plural allomorphs, -s (e.g., *horloge–horloge-s* "watches") and -(e)n (e.g., *boek–boek-en* "books") that can be predicted with high accuracy (more than 90%) from the word-final phonology of the singular: hence, in terms of predictability Dutch plurals are either highly predictable or exceptional (Table 1). German plurals are formed by four different plural suffixes, -s (e.g., *Auto–Auto-s* "cars"), -(e)n (e.g., *Katze–Katze-n* "cats"), -e (e.g., *Bus–Buss-e* "buses"), -er (e.g., *Bild–Bild-er* "pictures"), or by a zero suffix (e.g., *Pullover–Pullover* "pullovers"). In contrast to Dutch, grammatical gender, besides word-final phonology of the singular, predicts the respective plural forms, yielding high, partial, and exceptional predictability (Table 2). As to Stem Transparency, in both languages, pluralization may involve no stem modification (e.g., German *Schlange–Schlange-n* "snakes"), a slight change (e.g., German word-final voicing as in *Bur[k]–Bur[g]-en* "castles"), or a substantial change (e.g., German stem vowel change or Umlaut as in *Knopf–Knöpf-e* "buttons").

To sum up: Although Suffix Predictability and Stem Transparency play a role in both languages, they may affect acquisition in different ways. Suffixes are more predictable in Dutch, with the vast majority of nouns taking a highly predictable suffix. However, there are more plural suffixes in German, and substantial stem change (Umlaut) is more frequent in German than in Dutch. Hence, if we take as point of departure the complexity of the plural systems, German-speaking children are expected to perform worse in a plural elicitation task than Dutch-speaking children. Furthermore, plural morphemes, like other bound morphemes, are unstressed, and therefore, less easily identifiable in the flow of speech. Hence, their acquisition might be problematic for children with CI.

The study reported in this paper will compare grammatical proficiency in 14 early implanted preschoolers with CI and 120 NH

Table 1
Suffix Predictability and Stem Transparency in Dutch.

Suffix/Stem	No change	Slight change	Substantial change
Highly predictable	boek–boek-en "books"	huis–hui[z]-en "houses"	gl[?s]–gl[az]-en "glasses"
Partially predictable	/	/	/
Exceptional	kok–kok-s "cooks"	/	/

Table 2
Suffix Predictability and Stem Transparency in German.

Suffix/Stem	No change	Slight change	Substantial change
Highly predictable	Schlange–Schlange-n "snakes"	Zwer[k]–Zwerg-e "dwarfs"	Knopf–Knöpf-e "buttons"
Partially predictable	Pfeil–Pfeil-e "arrows"	Bur[k]–Burg-en "castles"	Fass–Fäss-er "barrels"
Exceptional	Bett–Bett-en "beds"	Hem[t]–Hemd-en "shirts"	Nashorn–Nashörn-er "rhinos"

children, in an experimental task designed to investigate children's noun plural production in Dutch and German. The analysis will focus on the following variables: Hearing status (CI, NH), Language (Dutch, German), and Suffix Predictability/Stem Transparency of the plural words. In addition, an analysis of the impact of Age-At-Implantation and of inter-individual variability on children's plural patterns will be provided.

2. Method

2.1. Participants

The study sample consisted of 14 preschool children who met the following criteria: (a) diagnosis of profound hearing impairment (>90 dBHL) in the first year of life, (b) cochlear implantation before the age of 24 months, (c) raised in normally hearing, monolingual families, (d) oral education, with or without the support of basic signs. Exclusion criteria were patent neurological disorders and/or general cognitive developmental delays.

The Dutch-speaking children (2 girls, 5 boys) were wearing a multichannel Nucleus-24 CI (Cochlear Corp., Sydney, Australia) and ranged in age from 49 to 67 months (Median (M) = 56 months) at the moment of testing. The German-speaking children (4 girls, 3 boys) were wearing a Sonata-ti100 CI (Med-El, Austria) and ranged in age from 46 to 63 months (Median (M) = 53 months). The device was implanted between the ages of 3–21 months (M = 12 months) and was activated approximately 1 month after surgery. The demographic data of these children are presented in Table 3.

The children with CI were matched with a control group of 80 NH children with the same Chronological Age at testing (Dutch-speaking NH group (N = 40): age range 46–69 months of age, Median (M) = 58 months; German-speaking NH group (N = 40): range 44–66, M = 56). In addition, a control group of 40 NH children with the same Hearing Age at testing (HA) was analyzed; Hearing Age in children with CI corresponded to the length of device use, i.e., Chronological Age minus Age At Implant Activation (Dutch-speaking HA group (N = 20): range 33–46, M = 42; German-speaking HA group (N = 20): range 36–45, M = 41). The children in the control groups were all typically developing monolingual speakers with no diagnosed speech, language, or hearing disorders and were recruited from a kindergarten in a mid-to-high SES neighborhood. For all children, written informed consent was obtained from the parents. The study was approved by the Ethics Committee of the University Hospital Antwerp (Belgium) and by the Ethics Committee of the Medical University of Vienna (Austria).

2.2. Materials and procedure

The test procedure was a plural elicitation task, which presented the participants with a set of singular nouns for which they had to provide plural forms [35]. A linguist administered the test in a quiet room, and each child was assessed individually. After a familiarization phase in which the procedure was trained, the actual test followed. The participants were seated opposite to the experimenter who was turning the pages of a binder on the table in front of the child. Each single page contained the picture of a single count noun, which was introduced by the experimenter as "This is a X" (for instance, "This is a dog"). On the next page two exemplars of the same individual entity were pictured, and the experimenter asked: "Now these are two of them, these are ..." and the child was invited to produce the plural form, as in "These are two dogs."

The stimuli for the two languages were chosen in a similar way. Stimulus words were balanced according to the relevant dimensions Suffix Predictability and Stem Transparency in the two languages. In selecting the stimulus words, care was taken to optimize the familiarity for the participants. For this reason frequent words were chosen from corpora of child-directed speech. And in addition the plurals of the test words were of middle to low frequency in child-directed words. The test consisted of 38 items in Dutch and 45 items in German. All test sessions were recorded using a high-quality digital audio recorder and were transcribed phonemically.

2.3. Data scoring and statistics

The answers of the participants were scored using a predetermined set of categories: (1) "No answer": the participant did not provide an answer to the test item, or replied with "I do not know" or an equivalent reply; (2) "Other lexical item": the

Table 3
Demographic data of children with CI.

ID	Language	Gender	Age at testing (months)	Age at (first) implantation (months)	PTA with device (dBHL)
P01	Dutch	M	67	3	35
P02	Dutch	M	55	21	22
P03	Dutch	F	66	18	25
P04	Dutch	F	66	11	35
P05	Dutch	M	56	10	22
P06	Dutch	M	49	6	38
P07	Dutch	M	53	11	36
P08	German	F	63	14	28
P09	German	F	46	10	30
P10	German	F	47	12	32
P11	German	F	55	20	30
P12	German	M	56	6	27
P13	German	M	53	10	27
P14	German	M	50	17	37

participant provided another lexical item than the one intended, e.g., in the Dutch test one of the test items was *roos* "rose", which some children replied to with the plural noun *bloemen* "flowers"; (3) "Other form": some answers contained the target noun, but it was changed, e.g., Dutch simplex nouns were sometimes rendered as diminutivized plurals by the children (*vis* "fish"–*vis-ke-s* "fish-DIM-PL"); (4) "Singular": the participant repeated the singular form given by the investigator; henceforth these answers will be referred to as "singular responses"; (5) "Plural provided": the items in this category were further coded in terms of the suffix provided, the presence of the relevant stem change(s), if applicable; henceforth these answers will be referred to as "plural responses." Eliminated from the data tables for subsequent analysis were the categories (1)–(3).

For the statistical analysis of the data, a logistic mixed-effects model approach based on maximum likelihood methods was used [44,45]. The most important advantage of mixed-effects models is that they allow the researcher to simultaneously consider not only standard fixed-effects factors and covariates, but also random factors (where only a random subset of factor levels is sampled from a larger population). In our case, such random effects are given by the sample of children (subjects) and test words (items), which are sources of variation that both need to be taken into account. Neglecting one of both variances, as would be the case in a traditional analysis on a by-subjects or by-items basis, would result in a higher chance of a type I error (incorrect rejection of the null-hypothesis).

Statistical modeling of the data was done in a stepwise manner. The point of departure was an empty (or null) model, where subjects and items were entered as random effects. In a next step, two word frequency measures (the lemma frequency LNFreqLemma and the plural token frequency LNFreqPl) were entered as fixed-effects covariates in order to control for possible frequency effects of the test words. Then, the fixed-effects factors of interest (e.g., Hearing) were sequentially added to the model. Finally, possible interactions between the fixed-effects factors were added. In each step, the statistical significance of the added factor was tested by a log-likelihood ratio Chi-square test. In Section 3, always the final, best fitting model of the analysis will be reported.

3. Results

3.1. Hearing, Language, and Suffix Predictability/Stem Transparency

The primary aim of the study was to investigate whether there exist differences in children's responses, depending on their Hearing status (CI, NH), on the language they learn (Dutch, German), and/or on the dimensions Suffix Predictability and Stem Transparency of the test words. For this purpose a statistical mixed-effects model with LNFreqLemma, LNFreqPl as fixed-effects covariates, and Hearing (2), Language (2), Suffix Predictability (3), and Stem Transparency (3) as fixed-effects factors was constructed (numbers in parentheses indicate the number of factor levels).

The analysis was performed for two data sets. The first data set consisted of children's plural responses, with the binomial outcome correct/incorrect plural as the dependent variable; the second data set consisted of children's repetitions of singular forms given by the investigator, with binomial singular/plural as dependent variable.

The mixed-effects model for plural responses showed no significant difference between children with CI and their NH peers (χ^2 (1) = 0.44, p = .507): with a median above 85%, both child groups performed equally well in producing correct plurals, see also Table A.1 in the Appendix. The impact of Language was close to significance (χ^2 (1) = 3.65, p = .056), indicating that Dutch-speaking children showed slightly higher success rates than German-speaking children. There was no significant interaction between the factors Hearing and Language: hence, CI and NH peers performed very similarly in the two languages. Significant effects were found for Suffix Predictability (χ^2 (2) = 16.21, $p < .001$) and Stem Transparency (χ^2 (2) = 47.31, $p < .001$): in both child groups, children followed the predicted pattern in that plurals with a highly predictable suffix reached a higher success score than plurals with a partially predictable suffix and those with an exceptional suffix. In the same vein: in both child groups, the probability of getting a correct response was higher for plurals that do not require a stem change than for plurals that require a slight stem change and for those with a substantial stem change, see Fig. 1. In addition, also word frequency contributed in explaining

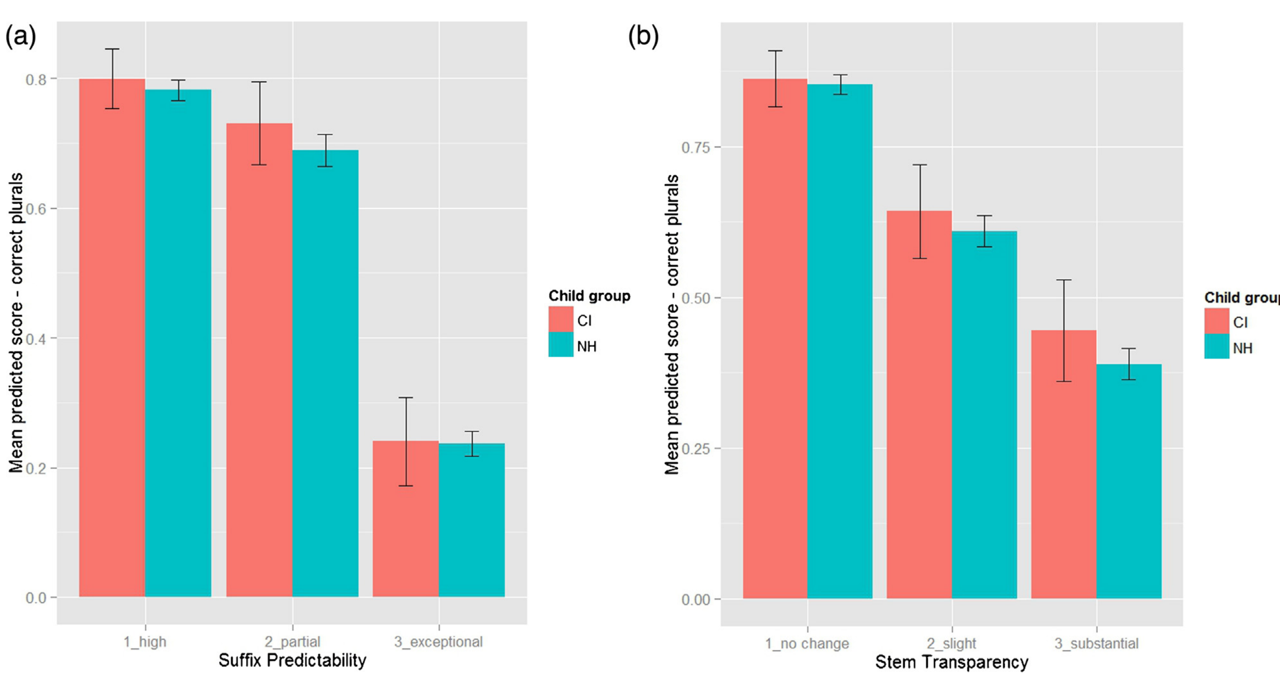

Fig. 1. (a and b) Mean predicted score of correct plurals by Suffix Predictability (left panel)/Stem Transparency (right panel) and by child group.

differences in correct plural responses (LNFreqLemma: χ^2 (1) = 5.38, p = .020). This means that plural forms of more frequent test words were easier for children than plurals of less frequent words.

The mixed-effects model for singular responses showed significant effects for the factors Hearing (χ^2 (1) = 23.01, $p < .001$) and Language (χ^2 (1) = 6.53, p = .011): with a median of 55%, children with CI significantly more frequently replied to the test item with the singular noun instead of the plural than their NH peers (median below 10%). There was also a significant difference between the German- and Dutch-speaking children in that respect. Suffix Predictability and Stem Transparency were not significant.

In order to see whether the difference in repetition of singular forms between children with CI and their NH peers might be due to differences in Hearing Age, we repeated the analysis for the control group of NH children matched for Hearing Age (HA), see also Table A.2 in the Appendix. This analysis yielded no significant effects for the factor Hearing (χ^2 (1) = 2.91, p = .088): children with CI and children in the HA group did not differ significantly in the repetition of singulars.

3.2. Age-At-Implantation

A second aim of the study was to focus on the group of children with CI and to examine whether there exist differences in children's responses, depending on the age at which the (first) CI was implanted. For this purpose a statistical mixed-effects model with the word frequency measures (LNFreqLemma, LNFreqPl), Chronological Age and Age-At-Implantation as fixed-effects covariates was constructed. The analysis was again performed for the two data sets of plural responses and singular responses.

The mixed-effects model for plural responses showed no significant effects for the covariates Chronological Age and Age-At-Implantation: younger and older children of our CI group did not differ significantly in correct plural responses and there was also no significant difference between earlier and later implanted children, see also Table A.3 in the Appendix. By contrast, the mixed-effects model for singular responses yielded significant effects for the covariate Age-At-Implantation (χ^2 (1) = 16.94, $p < .001$), indicating that earlier implanted children less frequently replied to the test item with the singular noun instead of the plural. The mean predicted score of correct plurals and repeated singulars by Age-At-Implantation (in months) is shown in Fig. 2.

3.3. Inter-individual variability

A third aim of the study was to focus on the group of children with CI and to examine inter-individual variability in children's plural responses at a more fine-grained level of analysis. For this purpose, the factors Suffix Predictability and Stem Transparency were partitioned into three levels each, resulting in a 3 × 3 Matrix, see also Tables 1 and 2 in Section 1.3. Then, a statistical mixed-effects model with Language (2) and Matrix cell (4 for Dutch, 9 for German, see Section 1.3) as fixed effects factors was constructed and the impact of each cell of the matrix on children's plural responses was tested.

The analysis showed a significant effect for Matrix cell (χ^2 (8) = 61.68, $p < .001$); Language was not significant, see also Table A.4 in the Appendix. The mean predicted score of correct plural responses by Matrix cell is shown in Fig. 3. As can be seen, the individual patterning was very similar across children with CI: children's success rates diminished from plurals with a highly predictable suffix requiring no stem change to exceptional plurals requiring a substantial stem change. This tendency was observed for all children with CI, with the only exception of the German-speaking child P11 who did not produce any plural forms and had to be excluded from this analysis. A Chi-square test of the distribution of correct plural responses by Matrix cell across participants confirms that there was no significant inter-individual variability in children with CI (Dutch χ^2 (18) = 8.36, p = .973; German χ^2 (40) = 14.96, p = .999). The same holds for the data set of normally hearing children. The main statistical results of Sections 3.1–3.3 are summarized in Table 4.

4. Discussion

Given its structural complexity and irregularity, noun plural formation is a good indicator of grammatical proficiency in normally developing children and in children at risk for a linguistic developmental delay [33,35,36,38]. The present study set out to

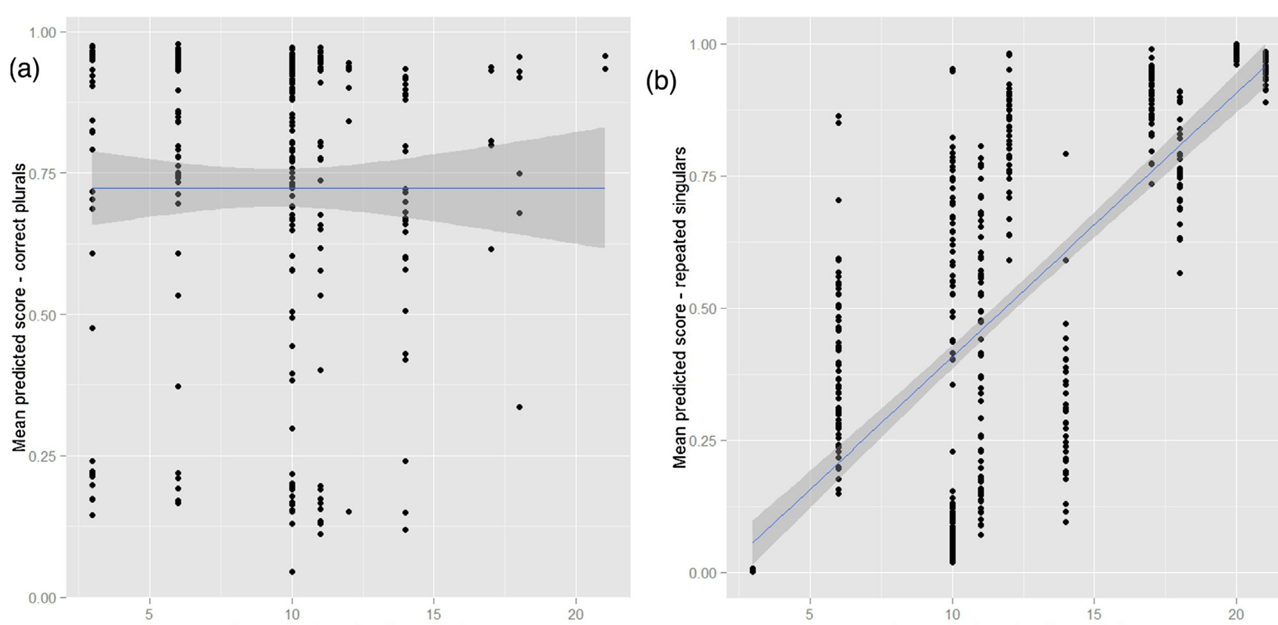

Fig. 2. (a and b) Mean predicted score of correct plurals (left panel)/repeated singulars (right panel) by Age-At-Implantation.

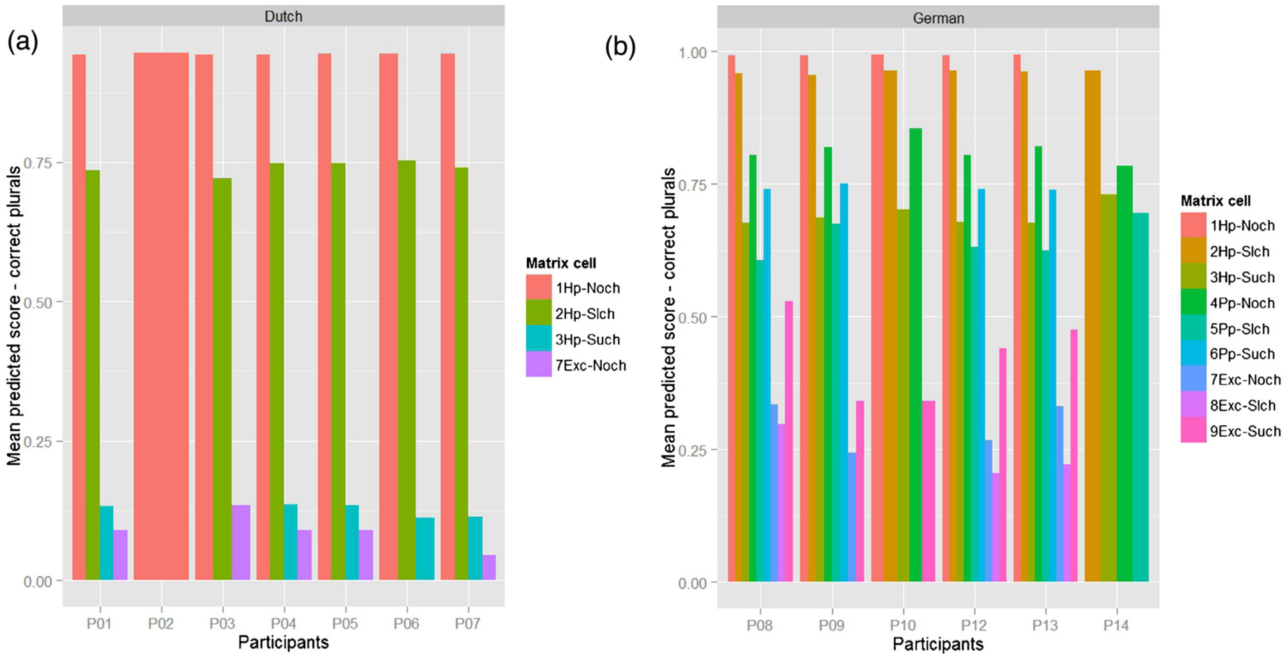

Fig. 3. (a and b) Individual patterning of correct plurals by Matrix cell for the 14 children with CI [key: Hp, highly predictable; Pp, partially predictable; Exc, exceptional; Noch, no change; Slch, slight change; Such, substantial change].

investigate noun plural production in Dutch- and German-speaking preschoolers with early cochlear implantation, as compared to their NH peers. The method used was a cross-linguistic experimental task designed to elicit noun plurals in Dutch and German. The analysis focussed on the following variables: Hearing status (CI, NH), Language (Dutch, German), and Suffix Predictability/Stem Transparency of the plural words. In addition, an analysis of the impact of Age-At-Implantation and of inter-individual variability on children's plural patterns was provided.

The results demonstrate that children in our CI group show age-appropriate patterns of noun plural formation: there was no significant difference between children with CI and their NH peers in correct plural production. In both child groups, plural responses followed the predicted pattern of Suffix Predictability and Stem Transparency: children attained a higher success score for plurals with a highly predictable suffix without a stem change, and a lower score for plurals requiring a substantial stem change and a less predictable suffix. This finding is consistent with earlier research on spontaneous speech data by Szagun [8,18], where the author found no significant difference in correct plural production between German-speaking children with CI and NH children matched by language level (MLU).

However, we also found evidence for delay in the acquisition of noun plurals by the CI group. This delay is manifested in a high number of repeated singular forms: children with CI significantly more frequently replied to the test item with the singular noun instead of the plural. Using a singular instead of the plural in plural contexts (e.g., *two dog*) is testified as a transient phenomenon in early child speech and experimental elicitation [30,35]. Our results suggest that in this respect the CI group patterns similar to the younger control group of normally hearing children matched by Hearing Age (HA). This developmental tendency is in line with the differences between children with CI and older and younger normally hearing control groups visible from the graphs in Svirsky et al. [7] for English elicitation data. In languages such as German where zero marking is a plural option (e.g., *Pullover–Pullover* "pullovers"), many erroneous early plurals take the zero form. Such forms are absent in Dutch child-directed speech. Accordingly, we also found a higher number of repeated singulars in the German than in the Dutch sample of our study.

Another result of interest is the impact of Age-At-Implantation on children's plural responses. In line with previous research, the findings of the present study indicate that children implanted in the first year of life show a better performance in a plural elicitation task. Longer auditory experience impacts positively on phonological short-term memory, which might be an important factor for the management of a plural elicitation task as used in this study [46]. The children in our study who received their CI before 12 months significantly less frequently gave a singular instead of a plural form and the probability of these responses increased with later age of CI implantation.

As to the question of inter-individual variability in the performance of children with CI, the results of the current study are two-edged. On the one hand, children with CI varied largely

Table 4
Summary of statistical results; . $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Results section	Dependent variable	Investigated variables
Section 3.1	Plurals	Hearing (ns) Language (.) Suffix Predictability (***) Stem Transparency (***)
	Singulars	Hearing (***) Language (*) Suffix Predictability (ns) Stem Transparency (ns)
Section 3.2	Plurals	Chronological Age (ns) Age-At-Implantation (ns)
	Singulars	Chronological Age (ns) Age-At-Implantation (***)
Section 3.3	Plurals	Language (ns) Matrix cell (***)

in the provision of plural forms (with not a single plural provided to our test words to 95% plurals provided). On the other hand, once children produced plurals, the individual patterning of noun plurals along the dimensions of Suffix Predictability and Stem Transparency was very similar across children with CI.

A final observation made in this study is that specific language structure plays an important role for children's plural responses. Our findings suggest that Dutch-speaking children show an overall better performance in a plural elicitation task than German-speaking children. This means that in a language like Dutch where plurals can be predicted with high accuracy from the word-final phonology of their singular forms, children "crack" the code more easily, leading to a higher number of correct responses [43]. This cross-linguistic difference is also reflected in the response patterns of our CI group.

5. Conclusion

This study demonstrated that after 3 years of implant use, early implanted children with CI show age-appropriate patterns of noun plural formation. However, they still have to catch up with respect to associating a particular singular with its plural form. In addition, it was shown that these phenomena should be framed in the specific languages with their particular structural impact on plural learners.

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Appendix A. Statistical results

Tables A1–A4.

Table A1
Mixed-effects model for the fixed-effects factors Hearing, Language, and Suffix Predictability/Stem Transparency (control group of NH children matched by Chronological Age).

Modeling steps	Plurals		Singulars	
	χ^2	p	χ^2	p
Intercept		<.001		<.001
Random part				
Subjects	28.59	<.001	1024	<.001
Items	1615.3	<.001	257.43	<.001
Fixed part (covariates)				
LNFreqLemma	5.38	.020	16.60	<.001
LNFreqPl	2.38	.123	1.49	.223
Fixed part (factors)				
Hearing	0.44	.507	23.01	<.001
Language	3.65	.056	6.53	.011
Suffix Predictability	16.21	<.001	2.84	.242
Stem Transparency	47.31	<.001	3.13	.209
Language × Stem Transparency	44.96	<.001		

Table A2
Mixed-effects model for the fixed-effects factors Hearing, Language, and Suffix Predictability/Stem Transparency (control group of NH children matched by Hearing Age).

Modeling steps	Plurals		Singulars	
	χ^2	p	χ^2	p
Intercept		.006		.010
Random part				
Subjects	1.84	.175	608.35	<.001
Items	567.99	<.001	133.89	<.001
Fixed part (covariates)				
LNFreqLemma	8.14	.004	16.87	<.001
LNFreqPl	2.00	.157	3.04	.081
Fixed part (factors)				
Hearing	6.211	.013	2.91	.088
Language	4.33	.037	2.09	.148
Suffix Predictability	11.09	.004	1.35	.509
Stem Transparency	55.22	<.001	2.06	.357
Language × Stem Transparency	41.66	<.001		
Hearing × Stem Transparency	10.67	.004	8.87	.012

Table A3
Mixed-effects model for the fixed-effects covariates Chronological Age and Age-At-Implantation (group of children with CI).

Modeling steps	Plurals		Singulars	
	χ^2	p	χ^2	p
Intercept		<.001		.993
Random part				
Subjects	0	1	264.14	<.001
Items	40.64	<.001	9.14	.002
Fixed part (covariates)				
LNFreqLemma	5.36	.021	8.74	.003
LNFreqPl	2.54	.111	0.44	.507
Chronological Age	0.181	.671	2.08	.149
Age-At-Implantation	0.59	.442	16.94	<.001

Table A4
Mixed-effects model for the fixed-effects factors Language and Matrix cell (group of children with CI).

Modeling steps	Plurals	
	χ^2	p
Intercept		<.001
Random part		
Subjects	0	1
Items	40.64	<.001
Fixed part (covariates)		
LNFreqLemma	5.36	.021
LNFreqPl	2.54	.111
Fixed part (factors)		
Language	0.61	.434
Matrix cell	61.68	<.001

References

[1] J.S. Moog, A.E. Geers, Speech and language acquisition in young children after cochlear implantation, Otolaryngol. Clin. North Am. 32 (1999) 1127–1141.
[2] C. Baldassari, C. Schmidt, C. Schubert, P. Srinivasan, K. Dodson, A. Sismanis, Receptive language outcomes in children after cochlear implantation, Otolaryngol. Head Neck Surg. 140 (2009) 114–119, http://dx.doi.org/10.1016/j.otohns.2008.09.008.
[3] S. Iwasaki, S. Nishio, H. Moteki, Y. Takumi, K. Fukushima, N. Kasai, et al., Language development in Japanese children who receive cochlear implant and/or hearing aid, Int. J. Pediatr. Otorhinolaryngol. 76 (2012) 433–438, http://dx.doi.org/10.1016/j.ijporl.2011.12.027.
[4] R.T. Miyamoto, K.I. Kirk, Communication skills in pediatric cochlear implant recipients, Acta Otolaryngol. (Stockh.) 119 (21) (1999) 9–224, http://dx.doi.org/10.1080/00016489950181701.
[5] J.R. Inscoe, A. Odell, S. Archbold, T. Nikolopoulos, Expressive spoken language development in deaf children with cochlear implants who are beginning formal education, Deaf. Educ. Int. 11 (2009) 39–55, http://dx.doi.org/10.1002/dei.252.
[6] B. Schramm, A. Bohnert, A. Keilmann, Auditory, speech and language development in young children with cochlear implants compared with children with normal hearing, Int. J. Pediatr. Otorhinolaryngol. 74 (2010) 812–819, http://dx.doi.org/10.1016/j.ijporl.2010.04.008.
[7] M.A. Svirsky, L.M. Stallings, E. Ying, C.L. Lento, L.B. Leonard, Grammatical morphologic development in pediatric cochlear implant users may be affected by the perceptual prominence of the relevant markers, Ann. Otol. Rhinol. Laryngol. 189 (2002) 109–112.
[8] G. Szagun, The acquisition of grammatical and lexical structures in children with cochlear implants: a developmental psycholinguistic approach, Audiol. Neurootol. 5 (2000) 39–47, http://dx.doi.org/10.1159/000013864.
[9] A.E. Geers, J.G. Nicholas, A.L. Sedey, Language skills of children with early cochlear implantation, Ear Hear. 24 (2003) 46S–58S, http://dx.doi.org/10.1097/01.AUD.0000051689.57380.1B.
[10] M.-T. Le Normand, C. Ouellet, H. Cohen, Productivity of lexical categories in French-speaking children with cochlear implants, Brain Cogn. 53 (2003) 257–262, http://dx.doi.org/10.1016/S0278-2626(03)00122-2.
[11] M.C. Caselli, P. Rinaldi, C. Varuzza, A. Giuliani, S. Burdo, Cochlear implant in the second year of life: lexical and grammatical outcomes, J. Speech Lang. Hear. Res. 55 (2012) 382–394, http://dx.doi.org/10.1044/1092-4388(2011/10-0248).
[12] T. Boons, L. De Raeve, M. Langereis, L. Peeraer, J. Wouters, A. van Wieringen, Expressive vocabulary, morphology, syntax and narrative skills in profoundly deaf children after early cochlear implantation, Res. Dev. Disabil. 34 (2013) 2008–2022, http://dx.doi.org/10.1016/j.ridd.2013.03.003.
[13] M.A. Svirsky, A.M. Robbins, K.I. Kirk, D.B. Pisoni, R.T. Miyamoto, Language development in profoundly deaf children with cochlear implants, Psychol. Sci. 11 (2000) 153–158.
[14] B. Richter, S. Eißele, R. Laszig, E. Löhle, Receptive and expressive language skills of 106 children with a minimum of 2 years' experience in hearing with a cochlear implant, Int. J. Pediatr. Otorhinolaryngol. 64 (2002) 111–125, http://dx.doi.org/10.1016/S0165-5876(02)00037-X.
[15] A.E. Geers, J.G. Nicholas, J.S. Moog, Estimating the influence of cochlear implantation on language development in children, Audiol. Med. 5 (2007) 262–273, http://dx.doi.org/10.1080/16513860701659404.
[16] A.E. Geers, J.S. Moog, J. Biedenstein, C. Brenner, H. Hayes, Spoken language scores of children using cochlear implants compared to hearing age-mates at school entry, J. Deaf Stud. Deaf Educ. 14 (2009) 371–385, http://dx.doi.org/10.1093/deafed/enn046.
[17] O.B. Wie, Language development in children after receiving bilateral cochlear implants between 5 and 18 months, Int. J. Pediatr. Otorhinolaryngol. 74 (2010) 1258–1266, http://dx.doi.org/10.1016/j.ijporl.2010.07.026.
[18] G. Szagun, The acquisition of grammar in young German-speaking children with cochlear implants and with normal hearing, in: K. Schauwers, P.J. Govaerts, S. Gillis (Eds.), Language Acquisition in Very Young Children With a Cochlear Implant, 102, Antwerp Pap. Linguist., 2002, pp. 40–60.
[19] E. Tribushinina, S. Gillis, S. De Maeyer, 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, Int. J. Pediatr. Otorhinolaryngol. 77 (2013) 356–361, http://dx.doi.org/10.1016/j.ijporl.2012.11.026.
[20] A. Hammer, M. Coene, J. Rooryck, P.J. Govaerts, The production of Dutch finite verb morphology: a comparison between hearing-impaired CI children and specific language impaired children, Lingua 139 (6) (2014) 8–79, http://dx.doi.org/10.1016/j.lingua.2013.11.010.
[21] M.A. Svirsky, S.-W. Teoh, H. Neuburger, Development of language and speech perception in congenitally, profoundly deaf children as a function of age at cochlear implantation, Audiol. Neurootol. 9 (2004) 224–233, http://dx.doi.org/10.1159/000078392.
[22] J.B. Tomblin, B.A. Barker, L.J. Spencer, X. Zhang, B.J. Gantz, The effect of age at cochlear implant initial stimulation on expressive language growth in infants and toddlers, J. Speech Lang. Hear. Res. 48 (2005) 853–867.
[23] J.G. Nicholas, A.E. Geers, Will they catch up? The role of age at cochlear implantation in the spoken language development of children with severe to profound hearing loss, J. Speech Lang. Hear. Res. 50 (2007) 1048–1062.
[24] J.K. Niparko, Spoken language development in children following cochlear implantation, JAMA 303 (149) (2010) 8–1506, http://dx.doi.org/10.1001/jama.2010.451.
[25] A. Lesinski-Schiedat, A. Illg, R. Heermann, B. Bertram, T. Lenarz, Paediatric cochlear implantation in the first and in the second year of life: a comparative study, Cochlear Implants Int. 5 (2004) 146–159, http://dx.doi.org/10.1002/cii.142.
[26] L. Duchesne, A. Sutton, F. Bergeron, Language achievement in children who received cochlear implants between 1 and 2 years of age: group trends and

individual patterns, J. Deaf Stud. Deaf Educ. 14 (2009) 465–485, http://dx.doi.org/10.1093/deafed/enp010.
[27] R. Brown, A First Language: The Early Stages, Harvard U. Press, Oxford, 1973.
[28] D.I. Slobin, The Crosslinguistic Study of Language Acquisition: Volume 2: Theoretical Issues, Lawrence Erlbaum Associates, Mahwah, NJ, 1985.
[29] G. Szagun, Learning different regularities: the acquisition of noun plurals by German-speaking children, First Lang. 21 (2001) 109–141, http://dx.doi.org/10.1177/014272370102106201.
[30] D. Ravid, W.U. Dressler, B. Nir-Sagiv, K. Korecky-Kröll, A. Souman, K. Rehfeldt, et al., Core morphology in child directed speech: crosslinguistic corpus analyses of noun plurals, in: H. Behrens (Ed.), Corpora in Language Acquisition Research: History, Methods, Perspectives, John Benjamins Pub. Co., Amsterdam; Philadelphia, 2008, pp. 25–60.
[31] R. Pfau, M. Steinbach, Pluralization in sign and in speech: a cross-modal typological study, Linguist. Typol. 10 (2006) 135–182, http://dx.doi.org/10.1515/LINGTY.2006.006.
[32] G.G. Corbett, Number, Cambridge University Press, Cambridge, UK; New York, 2000.
[33] G.F. Marcus, S. Pinker, M. Ullman, M. Hollander, T.J. Rosen, F. Xu, et al., Overregularization in language acquisition, Monogr. Soc. Res. Child Dev. 57 (1992), doi: 10.2307/1166115.
[34] K.-M. Köpcke, The acquisition of plural marking in English and German revisited: schemata versus rules, J. Child Lang. 25 (1998) 293–319.
[35] S. Laaha, D. Ravid, K. Korecky-Kröll, G. Laaha, W.U. Dressler, Early noun plurals in German: regularity, productivity or default? J. Child Lang. 33 (2006) 271–302, http://dx.doi.org/10.1017/S0305000906007379.
[36] D. Ravid, R. Schiff, Morphophonological categories of noun plurals in Hebrew: a developmental study, Linguistics 47 (2009) 45–63, http://dx.doi.org/10.1515/LING.2009.002.
[37] R. Schiff, D. Ravid, S. Levy-Shimon, Children's command of plural and possessive marking on Hebrew nouns: a comparison of obligatory versus optional inflections, J. Child Lang. 38 (2011) 433–454, http://dx.doi.org/10.1017/S0305000909990547.
[38] L.B. Leonard, J.A. Eyer, L.M. Bedore, B.G. Grela, Three accounts of the grammatical morpheme difficulties of English-speaking children with specific language impairment, J. Speech Lang. Hear. Res. 40 (1997) 741–753, http://dx.doi.org/10.1044/jslhr.4004.741.
[39] D.I. Slobin, Form-function relations: how do children find out what they are? in: M. Bowerman, S.C. Levinson (Eds.), Language Acquisition and Conceptual Development, Cambridge University Press, 2001, pp. 406–449.
[40] S. Laaha, S. Gillis (Eds.),Typological perspectives on the acquisition of noun and verb morphology (=Antwerp Pap. Linguist. 112) Antwerp (2007).
[41] S. Eisenbeiss, Production methods in language acquisition research, in: W.B.T. Blom, S. Unsworth (Eds.), Experimental Methods in Language Acquisition Research, John Benjamins Pub. Company, Philadelphia, 2010, pp. 11–34.
[42] S. Laaha, Sonority, gender and the impact of suffix predictability on the acquisition of German noun plurals, Lang. Interact. Acquis. 2 (2011) 82–100, http://dx.doi.org/10.1075/lia.2.1.04laa.
[43] S. Gillis, S. Laaha, R. Levie, S. deMaeyer, W. Dressler, D. Ravid, Why are (some) noun plurals hard to acquire? An experimental study of Dutch, German, and Hebrew, 2014 (unpublished).
[44] R.H. Baayen, D.J. Davidson, D.M. Bates, Mixed-effects modeling with crossed random effects for subjects and items, J. Mem. Lang. 59 (2008) 390–412, http://dx.doi.org/10.1016/j.jml.2007.12.005.
[45] D.M. Bates, lme4: mixed-effects modeling with R, 2010 (unpublished).
[46] M. Giezen, Speech and Sign Perception in Deaf Children With Cochlear Implants, LOT, Utrecht, 2011.