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Research article

Differences in picture naming between children with cochlear implants and children with typical hearing

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ABSTRACT

Increase in the auditory abilities of children with cochlear implants (CIs) has led to an improvement in naming tasks, although divergent results are still being reported; this strongly suggests that further studies are needed. The study aims to compare the responses in a picture-naming activity between the complete population of children aged 5 to 7 with cochlear implants in Catalonia -Spain- (N = 31), without developmental problems, and a matched sample of 31 children with typical hearing. A picture-naming task was used to assess their lexical naming abilities. The results show that children with CIs provide more non-responses, they produce fewer words correctly, they require a longer reaction time and they commit more picture-naming errors than children with typical hearing. The auditory age does significantly affect the results, but not the type of implant. In spite of the hearing gain achieved with the cochlear implant and the listening experience progressively achieved in distinct contexts, further explicit work on lexical naming in speech-therapy intervention is clearly required.

1. Introduction

Technological improvements in hearing devices in the past decade have contributed to improving auditory perception and, consequently, oral-language development in early-deaf children, especially in the area of lexicon (James et al., 2008).

There are many variables implicated in the lexical learning of children with cochlear implants (CIs), but two of these have been shown to be more strongly associated: the age at which the implants are implanted, known as the age of implantation, and how long the person has worn the implant, known as the auditory age (Bayés, 2017; Connor et al., 2006; Convertino et al., 2014; Dettman et al., 2007; Geers et al., 2008; Geers and Nicholas, 2013; Hayes et al., 2009; Holt and Svirsky, 2008; Houston et al., 2012; Miyamoto et al., 2008; Nicholas and Geers, 2007; Szagun and Stumper, 2012). Implants performed before the age of two allow children to reach similar oral-language levels to their same-age peers with typical hearing, as their age of language acquisition is the same as that of children with typical hearing, a variable considered as the greatest predictor of success in the ability to name in lexical processing, even more than the variable of word frequency (Cannard and Kandel, 2008). The study by Hayes et al. (2009) reaches this same conclusion after studying children aged 5 to 8 with CIs immersed in an oral-educational programme, along with the study by Connor et al. (2006), which examined a sample of 6-year-old children. Geers and Nicholas (2013) evaluated the linguistic competence of 60 children with CIs when they were 4 and 10 years old and found that the language levels they reached correlated significantly with their auditory age; they showed higher scores in vocabulary than in the other areas, although type of cochlear implant, either unilateral or bilateral, bore no influence. The improvement with cochlear implants in the lexical component takes place regardless of the type of implant, whether unilateral, performed in one of the ears, or bilateral, performed in both ears (Geers and Nicholas, 2013; Bayés, 2017).

The characteristics of the words generate the same lexical learning pattern in children with implants as in children with typical hearing of the same age. Neither word length nor phonological components influence word learning, whereas neighbourhood density (the number of known words that sound similar to a given word) and word frequency do (Kyung Han et al., 2015). The results of the recent study by Lund (2019) concur that children with CIs tend to know words with both high density and common probability or sparse density and rare probability.

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In addition to the studies indicated, other studies have reported different results in the areas of lexicon between children with CIs and children with typical hearing of the same age. Lund's (2016) review of studies examining the vocabulary of deaf children with CIs (average participant age ranged from 49 to 109 months) found that they still show lower expressive and receptive lexical knowledge than their same-age peers with typical hearing (Davidson et al., 2014; El-Hakim et al., 2001; Nott et al., 2009; Marshall et al., 2018; Svirsky et al., 2004). Le Normand et al. (2003) observed a considerable individual variability in lexical acquisition, in the fact that some children obtained a level close to the expected level for their age two or three years after implantation, while others displayed a long delay with little or no production. Moreover, the studies also found that a good level in one lexical category does not predict similar scores in other categories. The influence of age of implantation as a significant variable in learning activities concerning new vocabulary was also questioned by Pimperton and Walker (2018).

Along the same lines, Duchesne et al. (2009) showed the heterogeneity of the population of deaf children in relation to their levels of language acquisition. The study examined receptive and expressive vocabulary and grammar achievement of 27 French-speaking children aged between 42 and 99 months, who received a CI at the age of one or two years. As a group, children exhibited language levels within normal limits in all standardized language measures. Nevertheless, examination of individual patterns revealed four different language profiles ranging from normal language levels in all domains to general language delay.

The picture-naming task is the most consolidated task in determining linguistic progress (Cannard and Kandel, 2008; Wechsler-Kashi et al., 2014) and its use in research serves to determine not only the lexical repertoire of the child (words he/she knows), but also whether or not there are difficulties in the production process of these new words.

Pérez Pérez (2013) indicates that in the process of lexical production, children with typical hearing can make errors (produce the wrong words) and/or can need more time to access the word (also known as reaction or latency time) than what is considered as normal (600 ms, according to Rodriguez-Ferreiro and Cuetos, 2011). The result of the work by Logan (1981) reveal a direct correlation between production errors and latency time (the more errors, the longer the latency time). In the production process, word characteristics have been shown to affect the precision and/or latency time of production (Cycowicz et al., 1997).

The picture-naming task has rarely been used to assess naming production in children with CIs. Some studies have used it to analyse the production of categories (Lund and Dinsmoor, 2016), others to analyse the phonology (Grandon et al., 2019). However, it can also help to determine if the learned lexicon is produced following the same pattern as children with typical hearing, which would help to specify the linguistic benefits of cochlear implants.

Wechsler-Kashi et al. (2014) used the picture-naming task to study the production of names and the verbal fluency in order to establish whether children with CIs have deficits in lexical organisation and access that are manifested through reaction time. The sample consisted of 20 children with CIs and 20 children with typical hearing between the ages of 7 and 10 years old. They were shown pictures of words varying in length, familiarity and neighbourhood density, and pertaining to basic semantic categories and they were asked to quickly name the images. No significant differences were found between the two groups in the total number of pictures named or the total response time. In the production process, the very familiar and shorter words were produced more quickly by both groups. These results support the argument that the auditory age and age of implantation correlated positively with naming skills: the deaf children who received their CIs at a younger age and who had an older auditory age were more skilled at naming very familiar bi-syllabic words.

In different conditions to those of Wechsler-Kashi et al. (2014), Hoog et al. (2015) analysed the quickness and precision of naming production in children with CIs, hard of hearing children, children who used signed language and children with typical hearing aged between 7 and 12. After a first phase of familiarisation with the words to ensure they were known by all the children in the sample, and through the use of distractors, the results showed that children with CIs made more precision errors than children with typical hearing, but they did not need more reaction time for production. Schwartz et al. (2013), using distractors too, agree that the response time is not a variable that establishes differences between the population with CIs and the population with typical hearing.

Boons et al. (2013) studied the errors made in the picture-naming task and compared them with the expressive vocabulary. They used *The Expressive One Word Picture Vocabulary Test* (EOWPVT), a standardised test to study the naming of objects, actions and concepts. The study sample consisted of 70 children with CIs aged 5 to 13 with those of their same-age peers with typical hearing. The picture-naming errors were analysed using 8 categories: (1) No answer; (2) Neologism; (3) Not related; (4) Circumlocution; (5) Related-Meaning-General; (6) Related-Meaning-Neighbour; (7) Related-Meaning-Specific; and (8) Related-Sound. The results showed that the most frequent conduct of children with CIs was (1)-No answer, and significantly lower results than children with typical hearing were found only in the number of responses with a neighbouring word from the same semantic field (6-Related-Meaning-Neighbour).

The goal of this study was to further examine the process of naming production based on the picture-naming task in children with cochlear implants. The aim was to establish whether the lexical naming abilities in children with CIs are the same as for children with typical hearing. First, we studied whether the number of words produced is similar to or less than that of children with typical hearing in order to contribute knowledge to the contradictory results generated by previous studies. Second, we wanted to establish whether children with CIs present a difficulty pattern in naming production similar to that presented by children with typical hearing in relation to production errors and latency time. Third, we want to contribute more evidence about whether the auditory age (i.e., the difference between the age and the implantation age) and the type of implant are relevant variables in the naming production process.

According to the results of previous works, and considering the characteristics of the sample, the present study presents the following hypotheses:

H1. *Analysis of the differences in the number of correct names produced.* As indicated by the review of the studies carried out by Lund (2016), in the picture-naming task, it is expected that children with CIs will produce a lower number of correct responses than children with typical hearing.

H2. *Analysis of the differences in the number of names not produced.* According to the results of the study by Boons et al. (2013), it is expected that children with CIs will remain silent (no answers) more times than children with typical hearing when a name is required, unlike explicit responses given when the answer is simply unknown ("don't know").

H3. *Analysis of the differences in production difficulties*. Along the same line as the study by Wechsler-Kashi et al. (2014), it is expected that children with CIs and children with typical hearing will show the same profile of production difficulties, but children with CIs will have more difficulties accessing the lexicon, needing more latency time.

H4. *Study of the influence of auditory age and type of implant on the number of names produced.* According to the results of the study by Geers and Nicholas (2013), it is expected that the naming production process in children with CIs of an older auditory age will produce a larger number of names, while the type of cochlear implant is not expected to be a relevant variable.

H5. *Study of the influence of auditory age and type of implant on production difficulties.* In children with CIs, fewer difficulties are expected to be found in children of an older auditory age while the type of cochlear implant is not expected to be a relevant variable.

2. Materials and methods

2.1. Participants

The study sample was comprised of 62 children, 31 deaf children with CIs and 31 children with typical hearing, with 18 girls (58%) and 13 boys (42%) in each group, and aged between 5 and 7 years (mean of 6.03 years and standard deviation of 0.71 in both groups) from public inclusive schools that use Catalan as the working language for all school content. All these subjects are children of hearing parents and use exclusively spoken language to communicate. The deaf-children group constitutes the entire population of schoolchildren at the indicated ages in Catalonia (Spain). They were enrolled in an oral communication programme in the Resource Centres for Persons with Hearing Impairments (CREDA, in its Catalan acronym). CREDAs are institutions that depend on the Catalan Government's Department of Education, whose objective is to provide speech therapy at inclusive schools in order to attend to students with hearing impairment. The specific selection criteria for deaf children were having prelinguistic deafness, wearing a cochlear implant (either unilateral or bilateral), using oral language as a means of communication; having an auditory age equal to or higher than two years old (two or more years post CI, whether unilateral or bilateral), and not having any associated disability that could justify production difficulties itself. A control partner with typical hearing was sought for each deaf child. Each deaf child's tutor selected a partner from the same year group of the same age and sex, with a similar socioeconomic level and an average academic level obtained from school results that was also comparable, who did not present any developmental problems. All the families, whether of the deaf or hearing participants, provided their written consent for their children to participate in the study and the study was approved by the Catalan Government's Department of Education.

2.2. Instruments

The materials used were images of names that differ in frequency of use, length and pertinence to distinct semantic fields (food, animals, objects, transport, musical instruments, professions and personalities). The differences in the characteristics of the words were not the goal of our study.

On the one hand, we presented the 28-color photos of the AREPA test (*Anàlisi del Retard de la Parla*) by Aguilar and Serra (2003), prepared by the authors for the phonological study of children from 3 years of age. This ensures that the images are suitable for the age range in our study. In addition, in order to increase the sensitivity of the instrument and to make it more discriminative, the name of 13 complementary words that appear in the test images was also requested (see Appendix A). That is, the children were asked to say 2 or 3 names for 11 of the images, but only when they correctly named the first one. For example, when the image of a "turtle" was shown, the word to name its "shell" was only requested if the child had previously said the word "turtle". Consequently, the number of words requested ranged from a minimum of 28 to a maximum of 41.

2.3. Procedure

The images were shown by speech therapists who were familiar with the usage of the test in the context of children with language disorders. Children were asked to name pictures with the following prompt: What is this? They were given a maximum of 4 s to answer, following the criteria applied by Wechsler-Kashi et al. (2014). If after this time span the child remained silent (no answer) or said that he/she does not know ("I don't know"), the next image was shown. All responses were recorded in audio and subsequently transcribed literally by two researchers (judge 1: NM; judge 2: CC); this was then revised independently by a third researcher (judge 3: IE).

When the image was not automatically recalled, the latency time between the presentation of the image and its naming was recorded.

2.4. Measures

Following the *Protocolo de Análisis de las Dificultades del Lenguaje* (Protocol of Language Difficulty Analysis) (PADIL) proposals of Pérez Pérez (2013), the responses were grouped into three categories: number of names correctly produced ("automatic picture naming", known and automatically produced names, and "latency picture naming", known names with a longer latency time of production than expected), number of names not produced ("no answer", in which the children remained silent, and "don't know", in which the name is declared unknown), and number of responses with production difficulties ("semantic difficulties", in which a name produced for the picture was inappropriate due to the semantic features of the word activated; "lexical-access difficulties", in which there was a longer latency time of production than expected,

Table 1. Descriptive statistics of the study sample.

	Children with typical hearing	Children with CI	Total sample
	n (%)	n (%)	n (%)
Gender			
Male	13 (42)	13 (42)	26 (58)
Female	18 (58)	18 (58)	36 (58)
Type of implant			
Unilateral		21 (67.7)	
Bilateral		10 (32.3)	
	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	6.03 (0.71)	5.97 (0.75)	6.0 (0.72)
Age of implantation (months)		26.58 (15.04)	
Auditory age (months)		52.03 (15.15)	
Types of responses in the naming task (counts)			
No answer	0.94 (1.24)	3.94 (3.49)	2.44 (3.01)
Don't know	0.68 (1.11)	1.0 (1.27)	0.84 (1.19)
Automatic Picture Naming	28.71 (5.14)	22.29 (6.41)	25.5 (6.61)
Latency Picture Naming	31.03 (4.95)	26.19 (5.90)	28.61 (5.93)
Semantic difficulties	0.36 (0.71)	0.36 (0.80)	0.36 (0.75)
Lexical access difficulties	2.45 (2.1)	3.39 (2.70)	2.92 (2.44)
Picture Naming errors	4.55 (3.14)	5.71 (3.53)	5.13 (3.37)

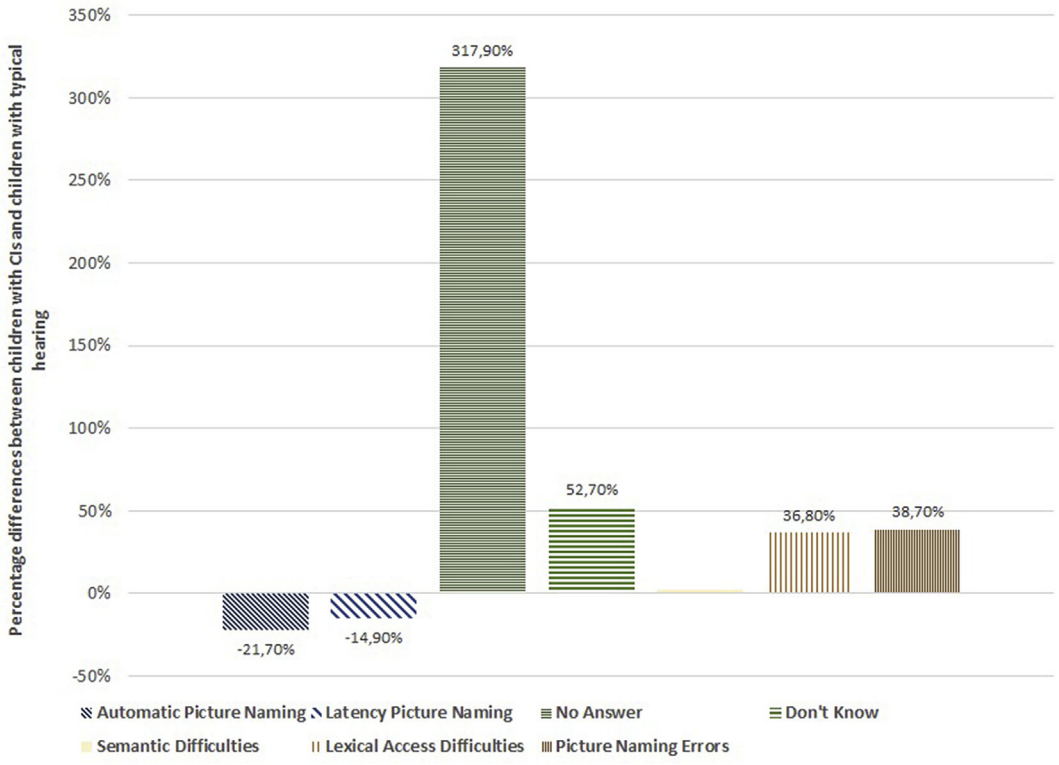

Figure 1. Adjusted differences (in percentages) between children with CIs and children with typical hearing in the picture naming task.

independently of whether the response was correct or incorrect; and "picture-naming errors", in which an incorrect name was produced). The complete coding of the PADIL categories is shown in Appendix B. Distinct works have established that the time from an image being seen and its name being vocalised is 600 ms (Rodriguez-Ferreiro and Cuetos, 2011). In this study, the consideration of difficulty of lexical access is advocated when the child takes more than a second to produce the word when being shown an image.

2.5. Data analysis

Considering the measurement scale of the outcomes registered (counts/number of instances) and the non-experimental nature of our study design (cross-sectional), Poisson regressions models were fitted to investigate the responses of children with CIs and children with typical hearing, as well as to analyse the influence of the type of CI, the auditory age in the group of children with CIs (Lindsey, 1995; Long, 1997; Vives et al., 2006). Variability in the number of words requested to each participant was included as an offset (exposure variable) in all Poisson regression models, and gender and age were included as control variables. The age at the time of implantation, which some authors also include in this type of analysis (Colin et al., 2017), was not considered in our case on account of the strong collinearity with the auditory age ($r = .82$; $p < .001$) due to the scarce variability in the age of the participants. The Incidence Rate Ratio (IRR) was calculated as the measure of relative risk, as well as its 95% confidence interval (95% CI) and p-values.

All statistics were processed with Stata/SE v16 (StataCorp, 2019).

3. Results

Table 1 summarises the main characteristics of the two groups of children studied, as well as the different responses recorded in the picture-naming task.

Results of the analyses conducted are presented below in the same order as the hypotheses. Figure 1 and Table 2 summarise the main results of the comparative analyses between children with CIs and children with typical hearing (hypotheses H1 to H3). Table 3 shows the results of the analyses within the group of children with CIs (hypotheses H4 and H5).

Table 2. Comparative analysis between children with CIs and children with typical hearing (reference group) in the Picture Naming task.

Measure	IRR_{adj} (95% CI)	$(IRR_{adj} - 1)*100$	P
Automatic Picture Naming	0.783 (0.708–0.864)	−21.7% (−29.2% – −13.6%)	<.001*
Latency Picture Naming	0.852 (0.776–0.935)	−14.9% (−22.4% – −6.5%)	.001*
No Answer	4.179 (2.786–6.270)	317.9% (178.6% – 527.0%)	<.001*
Don't Know	1.527 (0.877–2.657)	52.7% (−12.3% – 165.7%)	.135
Semantic Difficulties	1.026 (0.444–2.371)	2.6% (−55.6% – 137.1%)	.952
Lexical Access Difficulties	1.368 (1.017–1.839)	36.8% (1.7% – 83.9%)	.038*
Picture Naming Errors	1.387 (1.112–1.731)	38.7% (11.2% – 73.1%)	.004*

Note: Adjusted Poisson regression coefficients (IRR_{adj}), 95% confidence intervals (95% CI) and p-values (P). ($IRR_{adj} - 1)*100$ show the differences expressed in percentage between children with CIs and children with typical hearing. All regression models include sex and age (in years) as adjustment variables.

* IRR_{adj} statistically significant.

H1. *Analysis of the differences in the number of correct names produced*

The number of names that the children knew was analysed in two conditions. First, we analysed the number of names that children knew and produced automatically (automatic picture naming), and second, we analysed the number of names that they knew but did not produce automatically but which, instead, involved a latency time in which the presentation of the picture and its naming exceeded 1 s (latency picture naming).

As shown in Table 2, significant differences were found between the two groups in the two situations studied in relation to hypothesis H1: the group of children with CIs knew and automatically produced between 13.6% and 29.2% fewer names than the children with typical hearing (IRR_{adj} = .783; 95% CI: .708–.864), and children with CIs produced between 6.5% and 22.4% fewer names with a latency time less than 1 s (IRR_{adj} = .85; 95% CI: .776–.935).

H2. *Analysis of the differences in the number of names not produced*

The study of the names that were not produced revealed two different behavioural patterns: remaining silent (No Answer) or verbalizing the fact that the item for production was not known (saying "I don't know").

As shown in Table 2, and as posited in hypothesis H2, the number of names not produced in which the children remained silent was between 2.8 and 6.4 times higher in children with CIs than in children with typical hearing (IRR_{adj} = 4.179; 95% CI: 2.786–6.270). However, no significant differences were found in the number of times both groups stated that they did not know the answer.

H3. *Analysis of the differences in production difficulties*

As posited in hypothesis H3, no significant differences between the two groups were found in the number of semantic difficulties. However, the results indicate that the hypothesis on lexical-access difficulties was not supported: we expected to find no significant differences between the two groups in picture-naming time yet the results showed that this is between 3.5% and 86.7% higher in children with CIs than in the children with typical hearing (IRR_{adj} = 1.368; 95% CI: 1.017–1.839). That is, children with CIs take more time to name than children with typical hearing.

In accordance with H3, significant differences were found in the picture-naming errors: the number of errors committed by children with CIs was between 11.2% and 73.1% higher than children with typical hearing (IRR_{adj} = 1.387; 95% CI: 1.112–1.731) (Table 2). With regard to the type of picture-naming errors, as expected, no significant differences were found between those made by children with CIs and by children with typical hearing.

H4. *Study of the influence of auditory age and type of implant on the number of names produced*

The results showed that the auditory age (amount of time the children had had the implant) has a direct and significant influence, with a maximum magnitude of 1.2% (IRR_{adj} = 1.006; 95% CI: 1.0–1.012), on the number of names automatically produced without latency (Table 3). However, the type of implant (unilateral or bilateral) did not significantly determine the number of names the children with CIs knew and produced either automatically (automatic picture-naming) or with latency time (latency picture-naming). The hypothesis on the influence of auditory age was supported, as was the hypothesis on the influence of the type of implant. As expected, wearing a unilateral or bilateral implant did not lead to significant differences in the number of names that the children knew and correctly produced without latency time.

H5. *Study of the influence of auditory age and type of implant on production difficulties*

In the group of children with CIs the results showed that the auditory age has an inverse and significant influence, with a maximum magnitude of 2.5%, on the number of picture-naming errors (IRR_{adj} = .987; 95% CI: .975–.998), but not in any of the other types of production difficulties studied (semantic difficulties and lexical access difficulties). However, no significant differences were obtained with regards to the implant in any of the production difficulties studied.

4. Discussion

The objective of this study was to further examine the naming production process with the picture-naming task in children with cochlear implants and to provide knowledge about the effect of implants. To do so, we studied the number of words produced, the difficulty patterns presented in production and the effect of the auditory age and the type of implant as relevant variables in naming production. The results show that deaf children with cochlear implants aged between 5 and 7, compared to children with typical hearing, produce a lower number of words, do not answer in a higher proportion, present a production time of more than 1 s (latency time) and make more production errors. The auditory age of children with CIs has proved to be a relevant variable in the production of automatic picture-naming and in the reduction of the number of errors, but not the type of implant, which has not significantly influenced the results.

These results are consistent with some earlier studies, strengthening the knowledge of the naming production process with the picture-

Table 3. Effects of type of implant and auditory age of the children with CIs in the Picture Naming task.

Error classification	IRR_{adj} (95% CI)	$(IRR_{adj} - 1)*100$	P
Automatic Picture Naming			
- Type of Implant (bilateral vs unilateral)	0.904 (0.755–1.082)	−9.6% (−24.5% – 8.2%)	.270
- Auditory Age (months)	1.006 (1.0–1.012)	0.6% (0% – 1.2%)	.049*
Latency Picture Naming			
- Type of Implant	1.034 (0.877–1.218)	3.4% (−12.3% – 21.8%)	.693
- Auditory Age	1.004 (0.999–1.010)	0.4% (−0.1% – 1.0%)	.127
Semantic Difficulties			
- Type of Implant	0.455 (0.089–2.314)	−54.5% (−91.1% – 131.4%)	.343
- Auditory Age	1.030 (0.983–1.079)	3.0% (−1.7% – 7.9%)	.210
Lexical Access Difficulties			
- Type of Implant	0.965 (0.591–1.576)	−3.5% (−40.9% – 57.6%)	.887
- Auditory Age	0.986 (0.972–1.001)	−1.4% (−2.8% – 0.1%)	.075
Picture Naming Errors			
- Type of Implant	1.023 (0.713–1.467)	2.3% (−28.7% – 46.7%)	.901
- Auditory Age	0.987 (0.975–0.998)	−1.3% (−2.5% – −0.2%)	.027*

Note: Adjusted Poisson regression coefficients (IRR_{adj}), 95% confidence intervals (95% CI) and p-values (P). $(IRR_{adj} - 1)*100$ shows the effect expressed in percentage of change. All regression models include sex and age (in months) as adjustment variables.

* IRR_{adj} statistically significant.

naming task, and they provide data in a different light to those presented by other works.

When analysing the activated lexicon, significant differences are found between the two groups in the number of correct responses. Regardless of whether the picture naming is automatic or takes some time to be activated, children with typical hearing produced a larger number of correct responses than the children with CIs, independently of their sex and age. As with some of the preceding studies (see the review by Lund, 2016), this study has therefore found a lower knowledge of nominal lexicon in children with CIs than in the control group. Moreover, unlike the results of the studies by Wechsler-Kashi et al. (2014), Hoog et al. (2015) and Schwartz et al. (2013), children with CIs needed more time to produce those words than the control children. That is, they needed latency times because these words were not produced automatically. Despite using the same task as in the previous studies, the procedure and the characteristics of the sample could explain such discrepancies in the results. For one thing, the Wechsler-Kashi et al. study (2014) explicitly requested that participants respond as quickly as possible, while our study did not require that participants respond quickly. Furthermore, it was observed in their study that responses were slower as a function of the length of the word. While their study only used monosyllabic and bisyllabic words, the present study included words of three and four syllables, which probably contributed to the increase in response times. Another factor that prevents direct comparison between the results of the two studies is the age of the participants. Our study comprised younger children (5–7 years old), while Wechsler-Kashi et al. (2014), looked at children from 7–10 years old and Hoog et al. (2015), examined children between 7 and 12 years old. This could explain why participants in our study took longer to respond. The analysis of the type of error produced by the participants with CIs versus children with typical hearing revealed no significant differences. Overall, these results concur with those found by Boons et al. (2013), with the exception that they found that the least frequent picture-naming errors in children with CIs were words named with a neighbouring word from the same semantic field.

When children with CIs are asked to name pictures, they do so in a different way to children from the control group. The differences lie in the behavioural pattern of non-response (remaining silent), which is significantly more common in children with CIs than in the group of children with typical hearing. These results match those found in the study by Boons et al. (2013) who observed that the most frequent conduct shown by children with CIs when the EOWPVT test was applied to them were responses of the type “no answer”. There can be different reasons that justify the lack of response, some of which could be related, for example, to a reduced lexicon or difficulty accessing the lexicon. A possibility could be that they simply do not know the word, in which case the cause of differences to the group of children with typical hearing would be a lack of lexical knowledge (Lund, 2016). Alternatively, they do not respond because they cannot retrieve the word from their lexical storage, in which case the differences with the group of children with typical hearing would lie in greater difficulty activating the word, which then leads them to stop trying (Boons et al., 2013). These different causes (reduced lexicon or difficulty accessing the lexicon) would require specific types of speech and language therapy. A reduced lexicon will require a focus on increasing lexical learning, while difficulty accessing the lexicon will require a focus on reducing word finding difficulties. These two objectives will indicate the use of different intervention strategies and procedures, as should always be the case when considering the individual characteristics of each child with a CI. Only when the children explicitly state that they do not know the word by actually expressing the fact that they do not know the answer can we be certain that this is the reason they do not answer, although even in these cases this should be asserted with caution. Counter to the hypothesis, the results of our study reveal that there are no significant differences between children with CIs and the control group with typical hearing in terms of the number of words they say they do not know. This similarity between the two groups shows that children with CIs have the same awareness of their own knowledge as same-age children with typical hearing. This is necessary to advance cognitively and, from an educational-psychology standpoint, it helps the teacher and speech therapist employ specific methodological strategies to foster student learning.

Finally, this current study found no differences in the number of words the children knew and could produce according to the type of implant (unilateral-bilateral). This is in accordance with other studies (Bayés, 2017; Geers and Nicholas, 2013). That find, the type of implant does not affect the number of words that these children know and correctly produce in the naming task. The fact that various studies analyzing language ability in children with CIs conclude that those with bilateral CIs perform no better than those with unilateral CIs highlights the need to carefully consider and evaluate the necessity of a second implant in each individual case. However, as we expected, the child's auditory age (24–71 months) has an effect on the naming task, as found in the majority of previous studies (Convertino et al., 2014; Dettman et al., 2007; Geers et al., 2008; Geers and Nicholas, 2013; Houston et al., 2012; Holt and Svirsky, 2008; Miyamoto et al., 2008; Nicholas and Geers, 2007; Szagun and Stumper, 2012; Wechsler-Kashi et al., 2014). The results of this study show that the auditory age has an effect on the number of names automatically produced without delay and on the number of picture-naming errors.

Therefore, we can conclude that even though deaf children who attend inclusive schools receive the same linguistic experiences and are exposed to the same academic curriculum as their classmates with typical hearing, they do not construct their nominal lexicon as accurately as their same-age peers with typical hearing. However, through the technological assistance of a cochlear implant that provides good auditory gains, they gradually improve as their auditory age increases.

It should be noted that the non-experimental nature of the study may limit the scope of our conclusions. Children with typical hearing were selected through a process of matching by age, sex, socioeconomic level and average academic level to maximise their comparability with the group of deaf children with CIs, thus reducing the potential confounding bias inherent in cross-sectional research designs. In any case, there can potentially remain certain confusion due to the fact that the information about the socioeconomic status of the participants was collected from the interview with the academic teacher-tutor in relation to the profession of the parents and the inference of their income level. Furthermore, only children without any developmental problems were included in the study.

A notable strength of our study is the high representativeness of the group of children with cochlear implants included, since they constitute the total population of children with this characteristic in Catalonia within the age range studied. However, the small sample size reduces the statistical precision of the estimated effects of the type of cochlear implant.

Further research into the lexical knowledge of children with CIs is clearly required, as is the exploration of whether word-form characteristics affect the naming differences observed in our population.

Declarations

Author contribution statement

Cristina Cambra and Encarna Pérez: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Josep-Maria Losilla: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Nereida Mena: Performed the experiments; Analyzed and interpreted the data.

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Data availability statement

The data that has been used is confidential.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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