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Morpho-Syntactic Reading Comprehension in Children With Early and Late Cochlear Implants

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Abstract

This study explores morpho-syntactic reading comprehension in 19 Spanish children who received a cochlear implant (CI) before 24 months of age (early CI [e-CI]) and 19 Spanish children who received a CI after 24 months (late CI [l-CI]). They all were in primary school and were compared to a hearing control (HC) group of 19 children. Tests of perceptual reasoning, working memory, receptive vocabulary, and morpho-syntactic comprehension were used in the assessment. It was observed that while children with l-CI showed a delay, those with e-CI reached a level close to that which was obtained by their control peers in morpho-syntactic comprehension. Thus, results confirm a positive effect of early implantation on morpho-syntactic reading comprehension. Inflectional morphology and simple sentence comprehension were noted to be better in the e-CI group than in the l-CI group. The most important factor in distinguishing between the HC and l-CI groups or the e-CI and l-CI groups was verbal inflectional morphology.

In recent years, an important number of studies about language development in children with cochlear implants (CI) have been published in different languages (Geers, Moog, Biedenstein, Brenner, & Hayes, 2009; Le Normand & Moreno-Torres, 2014; Moreno-Torres, 2014; Ouellet, Le Normand, & Cohen, 2001). Many of these have examined the way that the atypical auditory perception of these children affects language development at various levels (phonological, morpho-syntactic, lexico-semantic, or pragmatic).

The CI substantially improves speech perception and production. It makes oral language development (Boons et al., 2012; Nicholas & Geers, 2007) easier. It also makes receptive vocabulary growth (Connor, Craig, Raudenbush, Heavner, & Zwolan, 2006; Svirsky, Stallings, Lento, Ying, & Leonard, 2002) easier in children with profound and prelingual deafness. On the other hand, there is little data available on the development of morpho-syntactic skills (see e.g., Boons et al., 2013; Szagun, 2004). The quantity and quality of these improvements depend on many variables,

such as the age of onset of the hearing loss, the residual hearing, the age at the time of cochlear implantation, experience with the implant, the nature and intensity of rehabilitation, family collaboration, mode of communication, intellectual level, type of implant, and so forth. (Miyamoto, Hay-McCutcheon, Kirk, Houston, & Bergeson-Dana, 2008; Spencer, 2004).

Children with severe and profound deafness can reach a true functional hearing level with the CI and can recognize familiar words and phrases without contextual aid. However, their hearing is not completely normal. Leybaert and Colin (2007) have pointed out that the CI stimulation is not as accurate as the natural acoustic stimulation. Thus the discrimination of phonetic contrasts such as voicing and place of articulation is far from perfect. These children need to learn to recognize and associate the phonological information with the auditory information provided by the CI.

Since the benefits of using CI for oral language development are well established, one expects that the use of CI will also have

a positive impact on reading decoding, as it facilitates the competent use of phonological strategies (Castles & Coltheart, 2004). There are many studies which examine how children with CI develop reading skills, especially at the lexical level, and which determine what are the most important variables in this development (Archbold et al., 2008; Kyle & Harris, 2006). However, relatively few studies address the impact that CI has on other reading abilities, especially in Spanish. For example, Pérez and Domínguez (2006) have established that the index of reading progress of deaf children without CI is 0.2 (meaning a deaf child only makes 20% of the progress a child in the hearing control [HC] group makes in 1 year), whereas the same index rises to 0.8 in children with CI.

Domínguez, Pérez, and Soriano (2007) reported a study comparing 71 deaf Spanish children, between 6 and 16 years old (53.5% with CI), and a control group (326 children) in the competent use of syntactic strategies. Their results indicated that children with CI differed from the rest of the deaf students in their use of syntactic strategies, but significant differences could still be found when compared to children in the control group. Deaf children without CI only employed semantic strategies based on key content words. Moreover, their results also showed differences within the group of children with CI depending on the age at the time of implantation.

In The Netherlands, Vermeulen, van Bon, Schreuder, Knoors, and Snik (2007) studied the comprehension of short paragraphs in deaf children who had been using their CI for at least 3 years compared to both deaf children without CI as well as to control children. All the children included in the sample were more than 7 years old. In contrast to previous work (Geers, 2003; Spencer, Barker, & Tomblin, 2003), Vermeulen et al. concluded that the lower reading comprehension performance levels by the children with CI in their study could be explained by the relatively longer duration of deafness and the delayed age of implantation.

The key skills for comprehensive reading development are those related to grammatical comprehension, which enable the integration of information across linguistic units such as words and phrases, all the way up to the sentence level. See the work of Monsalve, Cuetos, Rodríguez, and Pinto (2002) and of Perfetti, Landi, and Oakhill (2005). Therefore, grammatical comprehension is the ability to assign correctly thematic roles to the constituents of a sentence in order to extract its meaning (*who did what to whom*). The linear order of lexical items and their hierarchical relationship (both of which are given by the syntax and morphological markers), as well as the semantic features of words, allow us to assign these thematic roles (Fernández & Anula, 2002).

In the area of language development, lexical and grammatical skills are usually associated with one another. Thus, in the early stages of language acquisition the size of a child's lexicon is a good predictor of his/her grammatical skills in English (Snedeker & Gleitman, 2004). This relationship has also been found to exist in Spanish, a romance language with a rich morphological system (Mariscal & Gallego, 2012). Therefore, it would be expected that children with CI would show parallel delays in these two domains. However, Geers et al. (2009) have showed that the percentage of children with early CI (e-CI; before 30 months in their study) that reach a proficient primary school language level (comparable to those of their peers with normal hearing) varies according to the language component which is examined: 50% in vocabulary and 33% in syntax.

The main purpose of this study is to test whether the morpho-syntactic reading competence of Spanish-speaking children with e-CI and late CI (l-CI) ranging from third to sixth grade is close to that of a group of HC children with the same age and educational level. As the previously cited results would suggest, the earlier the CI is received the better the results will be. Specifically, it is expected that children with e-CI will show a morpho-syntactic reading comprehension level close to that of HC children. On the other hand, since the previous evidence showed that early implantation has more robust effects on language development and reading comprehension than l-CI, it is expected that children with l-CI will differ significantly from their peers in the HC group and also from the children with an e-CI. Additionally, we have attempted to determine which morpho-syntactic factors provide better discrimination between groups. We have also attempted to establish which aspects might form part of an intervention program to improve reading comprehension in children with CI.

Method

Participants

A total of 57 primary school children from 8 to 12 years of age participated in the study; 19 had a CI placed before 24 months of age (e-CI), another 19 received it between 24 months and 5 years of age (l-CI), and a final 19 children formed the HC group. All the selected participants in the study had a similar perceptual reasoning score, as measured by three WISC-IV (Weschler Intelligence Scale for Children Fourth Edition; Weschler, 2004) subtests on that ability (block design, picture concepts, and matrix reasoning). There were no statistically significant differences between the groups regarding perceptual reasoning (see Table 1).

All those children with attention deficit or learning difficulties and those with low IQ (IQ <85) or low birth weight were excluded from this study. Children with low birth weight were not included in order to eliminate the possible adverse effects of potential brain dysfunction or developmental delays (Verkerk, Jeukens-Visser, van Wassenaer-Leemhuis, Kok, & Nollet, 2014). Children with malformed cochlea were also not enrolled.

The institutions that collaborated in this research (children's hospitals, schools, associations of the deaf) only selected cases of children with CI that presented a history of severe or profound hearing loss (higher than 70 dB), and who were diagnosed in prelingual phase (before 24 months).

Table 2 contains detailed information concerning the average age in months and the standard deviation, as well as the number of males and females, by group. We checked that there were no statistically significant age differences between the groups.

Table 3 gives the mean and the standard deviation of the ages (in months) of the first implantation and of the first hearing device for the groups of children with CI. It also presents the percentages of current hearing status (unilateral or bilateral CI) and current hearing aid and etiology by group. Note that

Table 1. Descriptive statistics by group and nonparametrical *U* between group comparisons in perceptual reasoning (WISC-IV)

Group	Mean	SD	Mann–Whitney *U*		
			1	2	3
1. Hearing control (HC)	107.32	10.71	—	161.50, *p* = .583	154.50, *p* = .452
2. Early CI (e-CI)	111.05	13.93		—	132.00, *p* = .163
3. Late CI (l-CI)	104.16	12.22			—

Note. CI = cochlear implant.

Table 2. Mean age in months and the number of males and females, by group

Group	Age in months		Gender	
	Mean	SD	Males	Females
Hearing control (HC)	116.11	14.749	6	13
Early CI (e-CI)	116.32	13.536	12	7
Late CI (l-CI)	118.58	14.072	11	8

Note. SD = standard deviation; CI = cochlear implant.

Table 3. Mean and standard deviations in variables of children with CI

	CI group			
	e-CI		l-CI	
	Mean	SD	Mean	SD
Age of first implant (months)	14.68	5.69	41.89	12.97
Age of first hearing device (months)	11.05	6.87	30.42	16.63
	%		%	
Number of implants				
Unilateral	52.6		78.9	
Bilateral	47.4		21.1	
Current hearing aid				
Bilateral implant	47.0		21.1	
Unilateral implant without hearing aid	31.8		57.9	
Unilateral implant with hearing aid	21.1		21.1	
Etiology				
Genetic	57.9		42.1	
Viral	5.3		5.3	
Unknown	36.8		52.6	

Note. The table also shows percentages by CI groups: hearing status, current hearing aid, and etiology. CI = cochlear implant; e-CI = early CI; l-CI = late CI.

the percentage of bilateral CI users is higher in the e-CI group (47%) than in the l-CI group (21%). There are many more (57.9%) unilateral CI users in the l-CI group than in the e-CI group (only 21.1%).

All the children were enrolled in public and private schools in Madrid and Castilla-La Mancha, two autonomous regions of Spain. None of the participants had any other sensory or neurological deficits that would prevent them from understanding instructions or reading.

Materials

The tests described in this section were part of a larger protocol that was used to study the reading abilities of Spanish children (aged from 8 to 11 years) some with normal hearing and some with CI. The assessment protocol for the present study included standardized tests and others developed ad hoc. Among the standardized tests four were selected from WISC-IV (Wechsler, 2004): three pertaining to perceptual reasoning (block design, picture concepts, and matrix reasoning) and the digit span subtest (digit forward and digit backward), as a measure commonly used to assess working memory. The Peabody Picture Vocabulary Test (PPVT-III; Spanish adaptation by Dunn, Dunn, & Arribas,

2006) was also used to assess the participants' level of receptive vocabulary.

Two specific tests were developed ad hoc for this study (Ecco-Prima and Morphological Awareness [MA]). They are described as follows:

ECCO-PRIMA

This is a shortened version of the sentence comprehension test, ECCO (*Exploración Cognitiva de la Comprensión de Oraciones*; *Cognitive Assessment of Sentence Comprehension*; López-Higes, Del Río, & Fernández, 2005), adapted for primary school children. This test assesses grammatical comprehension through a simple verification task using sentence-picture pairs. The test consists of 36 items that belong to 12 sentence structures. Each structure differs from others through the propositional density (the number of propositions), and the word order (which can fit or not the canonical order for the Spanish language subject-verb-object [SVO], as shown in Table 4).

The ECCO-Prima test includes three item types for each sentence structure: one congruent (the sentence is associated with a picture that accurately reflects its meaning), a lexical foil (the action or any argument changes when comparing the sentence and the picture), and a syntactic foil (the picture represents an event where the roles of the participants are switched with respect to the action or the event denoted by the sentence).

The ECCO-Prima test assesses the thematic role assignment, which is an important part of sentence comprehension. The key determinants for that assignment are the linear word order, the existence of morphological markers, and semantic features such as animacy/inanimacy (MacWhinney et al., 1984). Access to the syntactic structure is imperative in understanding sentences in which the assignment of thematic roles is not restricted by pragmatic or semantic factors (semantically reversible sentences: *The man is pushed by the woman*).

Most Spanish sentences follow the canonical SVO word order, meaning that the word located in the initial position has the greatest prominence as an argument and receives the thematic role of the agent or actor. However, in the Spanish language, the linear position of the constituents can vary depending on discursive and contextual factors (e.g., *El libro que escribió la maestra* [*The book that wrote the teacher; "The book that the teacher wrote"; see Gutiérrez-Bravo, 2005]).

Passive sentences are a paradigmatic example of a syntactic structure where the correspondence between the linear order of words and the assignment of thematic roles is altered. The linear order of constituents corresponds to the semantic actor-event-patient interpretation in sentences that include a subject relative clause (*El guardaespaldas que salvó al presidente fue despedido*; The bodyguard who saved the president was fired). This correspondence fails in sentences that include an object relative clause (*El guarda que el presidente salvó fue despedido*; The bodyguard who the president saved was fired). The violation of the canonical word order makes the processing and interpretation of the last type of sentence more difficult (Ferreira, 2003). Thompson and Shapiro (2007) identified the number of propositions (associated with the number of verbs, which in turn aligns with the number of clauses) as one of the variables that contribute to sentence complexity.

MA test

This test assesses different aspects of MA in the written Spanish language, such as nominal, derivational, and verbal inflectional morphology. Derivational morphology studies word formation both through derivation (i.e., whereby a new word is formed by adding an affix to a root; e.g., *painter* and *painting* from the root

Table 4. Sentence structure types included in the ECCO-Prima

Sentence structures	Number of propositions	Fit to canonical word order in Spanish	Examples
Passive	1	No	El hombre es adelantado por el caballo. (The man is passed by the horse)
V-PrepP-NP Passive	1	Yes	Es despertado por el hombre el niño. (The boy is awakened by the man)
V-NP-PrepP Passive	1	No	Es atacado el gato por el niño. (Attacked is the cat by the boy)
Subject passivized relative clause	2	Yes	El perro que está arrastrando al gato es pequeño. (The dog that is dragging the cat is small)
Object passivized relative clause	2	No	El gato que el caballo está persiguiendo es blanco. *(The cat that the horse is chasing is white)*
Active	1	Yes	El caballo mordió al perro. (The horse bit the dog)
Subject nested relative clause	2	Yes	El perro que mordió al caballo es grande. (The dog that bit the horse is big)
Object nested relative clause	2	No	El perro al que el niño arrastró es pequeño. (The dog that the boy dragged is small)
Subject–object relative clause	2	No	El perro al que el gato mordió, empuja al niño. (The dog that the cat bit, push the boy)
Object–subject relative clause	2	Yes	El niño besó a la mujer que arrastra al perro. *(The boy kissed the woman that drags the dog)*
Focalized subject	1	Yes	Es el perro el que mordió al gato. (It is the dog that bit the cat)
Focalized object	1	No	Es a la mujer a la que despierta el hombre. (It *was the women that was awakened by the man*)

Note. Sentence features in relevant dimensions (the number of propositions and whether it fits the canonical word order in Spanish) appear at the center of the table.

paint) and through composition (i.e., whereby two or more words form a new word; e.g., *sunset*). Inflectional morphology studies variations in word form which have consequences in agreement and in other aspects of syntactic constructions. The MA test contains 47 "fill in the blank sentences." Nominal inflectional morphology includes gender and number agreement in regular nouns, whereas the verbal type considers the correct use of tense, person, number, and nominal forms (infinitive, participle, and gerund) of regular and irregular verbs.

Nouns in Spanish can be inflected to indicate number and gender. Verbs are also inflected to indicate tense, mood, person, and voice. The inflection can take the form of a suffix, a change in the beginning or end of a word, or a change in the way the word root is formed. Suffixes and altered word endings are the most common inflections. For example, in Spanish it is common to add an "-s" or "-es" to indicate that a word is plural and to change word endings to indicate gender (example: *niñ-o*, *niñ-a* [boy, girl]). To indicate simple verb tenses (present, past, and future) Spanish speakers can add a suffix or change the word ending (examples: *cant-o*, *cant-a-ba*, *cant-a-ré* [I + sing, sang, will sing]). Changes in the stem are also used in some irregular verbs (e.g., *voy* changes to *fui* [I go – I went]). Spanish like English uses auxiliary verbs (*haber* [to have]) to indicate other tenses such as present or past perfect. The use of other auxiliary verbs is also possible, for example, the progressive tense (*Yo estoy comiendo* [I

am eating]) indicates that the action is continuing. The following are two examples of the types of items included in the MA test:

2a. El niño presionó todos los botones de la _____
(The boy pressed all the buttons on the _____)
lavandería (*laundry*, feminine noun); lavandera (*laundress*, feminine noun); lavadora (*washing machine*, feminine noun); lavabo (*washbasin*, masculine noun).
2b. Habitualmente, yo _____ varias horas hasta llegar a casa
(I usually _____ several hours to get home)
conducimos ([we] *drive*, first person plural present tense of the verb 'drive'); conduje ([I] *drove*, first person singular past tense of the verb 'drive'); conductor (*driver*, masculine noun); conduzco ([I] *drive*, first person singular present tense of the verb 'drive').

Finally, in order to confirm the external validity of our tests of grammatical comprehension and MA we used the grammatical structures (GS) subtest of PROLEC-R (Cuetos, Rodríguez, Ruano, & Arribas, 2007), a Spanish standardized reading test that uses a picture-sentence matching task. It includes 16 items, each consisting of four pictures and one sentence. One picture corresponds to the meaning of the sentence and the other three are given as distractors or foils. In one of the pictures the subject and object roles are reversed with respect to the meaning of the sentence. The other two foils are semantic distractors. The GS subtest includes active and passive sentences, as well as focalized complement and relative clause sentences.

Procedure

The entire set of tests was administered in different sessions (on at least two different days) and in a random order for each child in the sample. Standardized tests from WISC-IV and GS (PROLEC-R) were administered to the participants following the standard instructions provided in the users' manuals.

In the MA test the children had to select a real word (noun, adjective, or verb) or a pseudoword, from a set of four possible alternative answers (a, b, c, or d), and fill in the blank to complete each sentence. Two examples were provided to the participants before starting the test. The children did not receive any feedback about their performance while the test was being administered.

The application of the ECCO-Prima began with five examples in which adequate feedback was provided to the children. If the participant understood the task, the presentation of the items began. Each pair of sentence-picture combinations appeared on the computer screen until the subject responded "True" or "False," at which point the evaluator clicked to present a new item on the screen. This procedure was repeated until the end of the test. During the testing period the appraiser did not provide feedback to the participant at any time.

Statistical Analyses

The IBM SPSS Statistics (v. 20) software package was used for the statistical analyses. For the ECCO-Prima test the total number of correct responses was obtained both for sentences which fit and did not fit the canonical word order in Spanish, and for sentences with one and two propositions. The total number of correct responses in lexical and syntactic foils was also obtained in order to explore the differences between groups by item types.

Regarding the MA test, two separate indices (number of correct responses) were obtained for nominal and verbal morphology. Spearman correlations were used to test the validity of the

ECCO-Prima and MA. To test the existence of differences between groups, the nonparametric Mann–Whitney U statistic was used.

A series of logistic regression analyses using Wald's forward stepwise method (HC vs. e-CI; HC vs. l-CI; e-CI vs. l-CI) was used for two ends. First, to determine the morpho-syntactic factors that allow an intergroup discrimination; second, to determine which aspects might form part of an intervention program meant to improve reading comprehension in children with CI. In each regression we used three sets of factors for classification: (a) nominal and verbal inflectional morphology, sentences fitting and not fitting the canonical word order in Spanish; (b) nominal and verbal morphology, sentences with one and two propositions; and (c) nominal and verbal morphology, lexical and syntactic foils.

Results

Table 5 shows the mean and standard deviation obtained by each group for each test used in the study.

Spearman correlations were calculated between the total scores of GS, ECCO-Prima, and MA in order to examine if these three tests measured related aspects. All of them were statistically significant ($p < .001$). The highest correlation observed occurred between GS and MA (.75), followed by ECCO-Prima and GS (.74), and finally the correlation between ECCO-Prima and MA (.72), which was slightly lower.

Between Group Comparisons: Were Any Differences Found With Respect to Age at Time of Cochlear Implantation?

Considering the standardized test we first observed that (a) the HC group had a significantly greater equivalent age in months in comparison with the e-CI group in receptive vocabulary ($U = 48.50$; $p < .001$); (b) comparing the HC group to the group of children with l-CI, the results indicated that there were

Table 5. Descriptive statistics by group in all the indexes extracted from the tests used in the study

	Group					
	Normal hearing		e-CI		l-CI	
	Mean	SD	Mean	SD	Mean	SD
Perceptual reasoning (WISC-IV)						
Matrix reasoning	12.00	2.06	12.95	2.76	11.84	3.10
Block design	10.95	3.44	10.74	3.31	10.32	2.89
Picture concepts	10.89	2.08	12.00	2.73	10.21	2.59
Perceptual reasoning index	107.32	10.71	111.05	13.93	104.16	12.22
Digit span subtest (WISC-IV)						
Backward digit span	3.84	0.69	3.74	0.93	3.26	0.93
PPVT-III						
Equivalent age in months	130.32	19.76	98.95	20.67	85.68	24.91
ECCO_Prima						
Sentences fitting CWOS	15.95	1.17	15.37	1.97	12.63	3.25
Sentences not fitting CWOS	13.10	1.79	12.47	2.77	10.89	2.76
Sentences with one proposition	15.47	1.61	14.31	2.26	11.58	2.93
Sentences with two propositions	13.58	1.92	13.52	2.43	11.95	3.08
Foils or distractors						
Lexical foils	9.05	1.81	9.42	2.06	7.79	2.32
Syntactic foils	9.32	1.37	8.11	2.58	6.68	2.43
Morphological awareness						
Nominal inflectional morphology	17.00	1.11	16.05	2.65	13.95	3.56
Verbal inflectional morphology	25.00	2.58	23.79	5.43	16.11	8.52

Note. CWOS = canonical word order in Spanish; e-CI = early cochlear implant; l-CI = late CI; PPVT-III = Peabody Picture Vocabulary Test.

differences in backward digit span ($U = 104.00$; $p < .03$), as well as in PPVT-III ($U = 32.50$; $p < .001$); (c) finally, children with CI (early vs. late) differed in their equivalent age in months in receptive vocabulary PPVT-III ($U = 103.5$; $p < .03$).

Regarding the effects of the age of implantation on MA test performance, results showed that: (a) the HC group and the e-CI group performed at the same level in nominal and verbal morphology; (b) the HC children's performance differed significantly from that of the children in the l-CI group, in both parts of the test ($U_{nominal} = 73.5$; $p < .002$; $U_{verbal} = 66.5$; $p < .002$); (c) children who received a CI before 24 months reached a higher performance level than that of children who received the CI later, both in nominal and in verbal morphology ($U_{nominal} = 102.5$; $p < .030$; $U_{verbal} = 81.0$; $p < .004$).

Comparisons between groups in ECCO-Prima's performance showed that: (a) children with e-CI had a grammatical comprehension level equivalent to that of the control (HC) group children in all the indexes considered in the analyses; (b) the HC group showed a better comprehension of all the sentence types (sentences fitting and not fitting the canonical word order in Spanish and sentences with one and two propositions) than the l-CI group ($U_{fitted} = 72.0$; $p < .002$; $U_{non\_fitted} = 94.0$; $p < .02$; $U1p = 42.5$; $p < .001$; $U2p = 112.5$; $p < .05$). Moreover, the l-CI group had more errors in syntactic foils than the HC group ($U = 73.05$; $p < .002$), but obtained a similar performance level in lexical foils to their control group peers; (c) children who received a CI before 24 months of age performed significantly better than their peers with l-CI in sentences fitting the canonical word order in Spanish and in sentences with only one proposition ($U_{fitted} = 84.5$; $p < .004$; $U1p = 90.0$; $p < .009$). When the type of item was considered, the analyses showed differences between the groups in lexical foils ($U = 107.5$; $p < .04$), but not in syntactic foils.

Morpho-Syntactic Factors Relevant for Subjects' Classification

A discriminant analysis was first performed, using the variables extracted from the morpho-syntactic tests and the groups as the criterion variable. The Box test for equality of covariance matrices was significant, thus failing to fulfill the assumption of homoscedasticity. Next we performed a series of logistic regression analyses (HC vs. e-CI; HC vs. l-CI; e-CI vs. l-CI). As was mentioned above, in each case the aim was to set three logistic models that included different factors: (a) the correct responses in nominal and in verbal morphology, as well as the results obtained in the sentences fitting and not fitting the canonical word order in Spanish; (b) the correct responses in nominal and in verbal morphology, as well as the results in sentences with one and in two propositions; (c) the correct responses in nominal and in verbal inflectional morphology, as well as in lexical and in syntactic foils.

Regarding the first three logistic regression analyses (HC vs. e-CI), the results showed that none of the previously mentioned factors entered in the final equations. New analyses (HC vs. l-CI) showed that verbal inflectional morphology performance alone allowed classifying 81.6% of cases (see Table 6 for statistics related to final equations). Regression analysis performed with the second set of factors showed that performance in sentences with one proposition was the only variable in the final equation, and that it correctly classified 78.9% of the total cases. In the final analysis, verbal inflectional morphology again correctly classified 81.6% of the cases.

Finally, the analyses computed to classify children who received a CI before and after 24 months of age (e-CI vs. l-CI) revealed that verbal inflectional morphology correctly classified 73.7% of the total sample in all cases (see the final part of Table 4).

Discussion

The results have suggested that both the ECCO-Prima and the MA tests have external validity since they are strongly related to GS subtest of PROLEC-R.

The pattern of results obtained in the standardized tests has indicated that HC children possess a receptive vocabulary (PPVT-III) which is significantly higher than that of children with e-CI and l-CI. Results also imply that these two later groups differ in this measure. In the group of children with l-CI, a gap has been

Table 6. Variables in final equations, variables excluded and related statistics for classifications (HC vs. l-CI; e-CI vs. l-CI)

	B	SE	Wald	df	Sig.	Exp(B)	Confidence interval at 95.0% for Exp(B) Inferior	Superior
HC versus l-CI								
Equation 1								
Verbal morphology	−0.288	0.107	7.207	1	0.007	0.750	0.608	0.925
Variables excluded:	Nominal morphology, sentences fitting canonical word order, sentences not fitting canonical word order							
Equation 2								
Sentences with one proposition	−0.741	0.238	9.670	1	0.002	0.477	0.299	0.760
Variables excluded:	Nominal morphology, verbal morphology, sentences with two propositions							
Equation 3								
Verbal morphology	−0.288	0.107	7.207	1	0.007	0.750	0.608	0.925
Variables excluded:	Nominal morphology, lexical foils, syntactic foils							
e-CI versus l-CI								
Equations 1, 2, and 3								
Verbal morphology	−0.154	0.058	6.985	1	0.008	0.857	0.765	0.961

Note. B = slope values; df = degrees of freedom; e-CI = early cochlear implant; Exp(B) = predicted odds ratio; HC = hearing control; l-CI = late CI; SE = standard error; Wald = Wald's forward stepwise method.

found between their average chronological age and the average equivalent age on the PPVT-III. The difference between the average chronological age and the average equivalent age on the PPVT-III was of 32.9 months in the l-CI group, and it was reduced to half approximately (17.37 months) in the e-CI children group. The mean equivalent age of the PPVT-III observed in the HC group indicates that these children exhibit a high level of receptive vocabulary, since that measure was higher than the average chronological age. Finally, the HC group had a higher backward digit span than that of l-CI children, indicating a significant difference in working memory span between those groups.

Children who received a CI before 24 months of age performed as well as the HC group on the tests assessing MA and grammatical comprehension, since no differences were found between these two groups in the analyses. The additional fact that the e-CI group reached an accuracy level in syntactic foils similar to that obtained by the HC group, is taken to indicate they were able to accurately detect the change in the assignment of thematic roles by comparing the corresponding sentence and picture, which led them to answer "false" in these items. This is also taken to imply that these children make use of some effective syntactic strategies to understand semantically reversible sentences (Soriano, Pérez, & Domínguez, 2006).

Children in HC group and their l-CI peers differed significantly in their MA (both nominal and verbal), as well as in all the indexes obtained through the grammatical comprehension test. The latter group also made a significant greater number of errors in syntactic foils than their control group peers, but showed a similar level of accuracy in lexical foils.

These results confirm the first part of our general hypothesis, an expectation that children who received a CI at an early age (before 24 months) would show a level of morpho-syntactic comprehension in reading close to that of children in HC group with the same age and educational level. On the contrary children with l-CI performed significantly worse in all the sentence types, considering both syntactic complexity and semantic density. Moreover, the number of errors that these children made in syntactic foils would indicate either that they have trouble assigning thematic roles to constituents in semantically reversible sentences, or that they do not use effective strategies. MA is also an area where these children presented a clear delay when compared to the HC group, as evidenced in the significant differences found in both nominal and verbal morphology indices of the MA test. The pattern of results that arises when comparing HC and l-CI groups might be a consequence of their differences in working memory and in receptive vocabulary. Some previous studies have shown a direct relationship between poor working memory span and smaller vocabulary size in children with CI (Stiles, McGregor, & Bentler, 2012). Furthermore, it is well known that parsing, integration processes, and thematic role assignment all require working memory resources, and it has been proved that this factor modulates the morpho-syntactic comprehension in normal children (Kyle & Harris, 2006) and in children with CI (Asker-Árnason, Wass, Ibertsson, Lyxell, & Sahlén, 2007). It must be taken into account that when the influence of working memory is analyzed jointly with variables related to the time of CI usage, the age of implantation loses its significance, and working memory appears as a strong predictor of grammatical development (Willstedt-Svensson, Löfqvist, Almqvist, & Sahlén, 2004).

The results of the e-CI group in this study, confirm those of other previous studies which show positive effects of early cochlear implantation on reading comprehension, especially after using the CI for 6 or 7 years (Connor, 2006; Svirsky, Robbins,

Kirk, Pisoni, & Miyamoto, 2000). Early placement of a CI appears to be positively related to the rapid emergence of first words, to greater social skills and motor control and to greater knowledge of the world (Moreno-Torres & Fredes, 2012).

Some studies, that is, Geers (2003) have found that about half of the 8- and 9-year-old children with an early CI (by 5 years of age) performed at or above the appropriate grade level on standardized reading tests. However, other studies have shown (Connor & Zwolan, 2004; Spencer, Gantz, & Knutson, 2004) that the level obtained by the majority of children with CI stood between one and two standard deviations below the mean of the normative group, a low but rather normal level. Some aspects make these studies difficult to compare (Marschark, Rhoten, & Fabich, 2007), as are the variety of procedures used to assess reading comprehension, or the specific characteristics of the CI sample of participants.

As an additional result of the present study, it should be pointed out that the differences in receptive vocabulary that were found between the HC and the e-IC groups, did not affect reading comprehension at its morpho-syntactic level. The difference of demands imposed by auditory word perception (PPVT-III) and by reading, might constitute a possible explanation. Written material allows for rereading or reviewing, which in turn facilitates comprehension, whereas in listening the stimulus may be retained only for a very limited amount of time. This conclusion conflicts with some previous studies that have shown a strong association between receptive vocabulary and reading comprehension in children with CI (Dillon & Pisoni, 2006; Dillon, de Jong, & Pisoni, 2012; Vermeulen et al., 2007). It seems that vocabulary explains a significant proportion of variance in grammatical outcomes in normal hearing Spanish children between 1.04 and 2.06 years of age (Mariscal & Gallego, 2012), as revealed in their scores on the vocabulary and grammar subsections of the European Spanish version of the MacArthur-Bates CDI.

However, some authors reported that the correlation between vocabulary and reading comprehension in normal hearing English-speaking students in primary school was only moderate (.49). The same holds for correlations obtained between morpho-syntactic competence and reading comprehension (Ripoll, 2011). The relationship between vocabulary and grammar development could be relevant only in the earliest stages of the language acquisition process and not necessarily in later stages. This possibility has been put forward by Moyle, Ellis Weismer, Evans, and Lindstrom (2007), on the basis of their study of vocabulary and grammar development in typically developing children and those with specific language impairment between 2.00 and 3.06 years of age. Our interpretation of the results regarding the relationship between receptive vocabulary and morpho-syntactic reading comprehension supports this latter suggestion.

Turning to the second part of the general hypothesis in the present study, it is necessary to examine the existence of differences between children with e-CI and l-CI. Comparing both groups shows that children who received a CI before 24 months of age present a significantly better performance in nominal and verbal inflectional morphology than the group of l-CI children. They show the same advantage in the comprehension of sentences that are fitted to canonical word order in Spanish, or that have only one proposition. Both groups differ too in the number of errors committed in lexical foils.

In our study, the e-CI group received their first hearing aid at about 11 months of age, whereas the l-IC group received it at the age of 30 months. Moreover, the l-IC group presents twice the variability of that observed in the e-CI group. As we

saw in Table 3, the average age of the first implant placement is approximately 15 months in the group e-CI and 42 months in group l-CI. If we consider hearing status, in the e-CI group there is a similar percentage of children using one and two CI, but in the l-CI group most children use a unilateral implant (79%). Considering the current hearing aid, in the l-CI group there was 58% of children wearing only one CI without other hearing aid, whereas the percentages of cases with two CIs or using one CI and having other hearing aid were both 21.1%. In the e-CI group, children using two CIs are more than twice as many as in the l-CI group. If we consider e-CI children using only one CI with contralateral hearing aid, the percentage of cases is the same as that observed in l-CI group. Regarding the children wearing one CI with no additional hearing aid, the l-CI group exceeds the percentage obtained by the e-CI group in this category by 26 points. Taking all these data together, we can observe that the distribution of cases along two of the current hearing aid categories (bilateral implant and unilateral implant without hearing aid) is quite different in the two groups of children using CIs. Finally, genetic etiology predominates in the e-CI group, whereas mainly unknown causes account for l-CI. Based on practical experience in pediatric clinic and in analysis of the literature, the best rehabilitation for a child affected by bilateral sensorineural deafness is early bilateral simultaneous cochlear implanting (Ramsden et al., 2012; Sparreboom, Langereis, Snik, & Mylanus, 2015). When bilateral implants are provided early and simultaneously, speech and language skills develop rapidly.

From our perspective, the age of implantation should be considered as a construct, and should be interpreted as such. Because of its technical and social nature, factors like: the age of the first hearing device, the status of current hearing aids, etiology, the socioeconomic status, new advances in technology or in surgery, among others, are necessarily implied. It is a reductionist view to consider that this construct is related only with the moment in which an action (cochlear implantation) was performed. Thus, the results obtained in this study should be interpreted from this perspective: The age of implantation, and its associated factors (age at fitting first hearing aid, current hearing status, etiology), explain the pattern of differences observed between groups in morpho-syntactic comprehension.

With respect to the final objective of the study, the results pointed out that none of the variables used allowed for the classification of HC and e-CI children. A moderate to high percentage of cases (81.6%) were correctly classified by verbal inflectional morphology in two equations when the selected categories were HC and l-CI, and a slightly lower percentage (78.9%) by performance in sentences with one proposition. Finally, and more interestingly, regarding the e-CI and l-CI categories, 73.7% of cases were correctly classified in the three analyses performed by verbal inflectional morphology, which shows that this factor seems to distinguish between these two groups in a consistent manner.

Conclusions

Cochlear implantation beyond 24 months of age is less beneficial for reading comprehension at a morpho-syntactic level than early implantation and there are specific effects on verbal inflectional morphology. In severe or profound prelingual deafness the expected level of hearing with conventional hearing aid fitting and training is residual effective, which means that the child can only gain around 50% in comprehension using lipreading with auditory support (Juárez, Monfort, & Monfort, 2005). This is the best possible situation for any child with severe or profound deafness before they receive a CI. If both the ambiguous phonological input and incomplete morpho-syntactic input persist for a longer period of time, as occurred in l-CI group, the consequences for language development will be quantitatively and qualitatively worse than in e-CI children.

However, a more in-depth explanation would state that sound deprivation or lack of an adequate input signal for an extended period of time has a negative effect on the maturation of auditory pathways, nuclei, and centers (Sainz & de la Torre, 2008). Therefore, after extensive periods of precochlear implant deprivation, the ability to establish relevant (phonological) contrasts should be affected. That is, it would be difficult to differentiate between similar words (such as different verb tenses) from the morphological point of view (see Johnson & Goswami, 2010, for an explanation of this view). It should be noted that the inflection markers in Spanish are located at the end of words and that this feature makes them especially difficult to discriminate. Some authors have proposed that the specific developmental sequence for grammatical skills in CI children is determined by the perceptual prominence of the relevant acoustic markers (Svirsky et al., 2002). In English, for example, the plural marker for nouns is perceptually more salient for children with CI than regular past tense markers are. This morpho-syntactic delay, first manifested in oral comprehension, is subsequently reflected in reading comprehension, as it provides the basis of the writing system (Perfetti & Sandak, 2000). On the other hand, an additional conclusion to be drawn from the results is the validity and usefulness of the two tests (ECCO-Prima and MA) which were developed for this study.

Since the final analysis highlights the role of verbal inflectional morphology as the most important factor to distinguish between HC and l-CI or between e-CI and l-CI children, this factor would be the core nucleus of a reading comprehension stimulation program at a morpho-syntactic level. These results give rise to the following recommendations for educational intervention:

1. Strengthen or explicitly incorporate the teaching of morpho-syntactic strategies to understand these structures (see e.g., Aguado, Ripoll, & Domezáin, 2003) in the reading instruction of children with CI, especially those with CI placed after 24 months of age.
2. Build upon the skills and competencies that control the facilitation of new learning in these children.

Children with l-CI require specific intervention in all morpho-syntactic issues considered in the study, with special emphasis on verbal morphology. In this case, the intervention goal is to establish a morpho-syntactic core competency in the child. The intervention in children with e-CI, if needed, should mainly focus on comprehension of complex sentence structures (with two propositions, or not fitted to canonical word order), given that no differences were found in these items between children with CI.

The results of this paper suggest some possible guidelines for intervention in reading comprehension at the morpho-syntactic level which could be particularly suitable for children with CI placed after 24 months of age:

1. Use exercises of discrimination with pairs of verb forms which manipulate morphological markers appearing at the end of the word (example: cant<u>ara</u> vs. cant<u>aba</u>); the pairs would become gradually more similar, thus increasing the difficulty of the task.
2. Conduct a program of implicit feedback training (see e.g., Mitchum & Berndt, 2001) using a simple verification task

(sentences-picture matching) with semantically reversible sentences; first fitted to canonical word order (SVO), with progressively more complex syntactic structures, and later on introducing sentences not fitted to SVO order of constituents.

The present study shows that an early CI has a positive impact on morpho-syntactic reading comprehension. However, despite the clear advantages of early implantation, the reading competence of children with an e-CI is not entirely the same as that of their peers with a typical hearing. This suggests that it would be valuable to use specific intervention programs oriented to an improvement of reading at the morpho-syntactic level.

Conflicts of Interest

No conflicts of interest were reported.

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