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ARTICLE

Development of communicative-pragmatic abilities in children with early cochlear implants

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Abstract

Cochlear Implants (CIs) enhance linguistic skills in deaf or hard of hearing children (D/HH). However, the benefits of CIs have not been sufficiently studied, especially with regard to communicative-pragmatics, i.e., the ability to communicate appropriately in a specific context using different expressive means, such as language and extralinguistic or paralinguistic cues. The study aimed to assess the development of communicative-pragmatic ability, through the Assessment Battery for Communication (ABaCo), in school-aged children with CIs, to compare their performance to a group of children with typical auditory development (TA), and to investigate if CI received under the age of 24 months promotes the typical development of such ability. Results show that children with CIs performed significantly worse than TA on the paralinguistic and contextual scales of the ABaCo. Finally, the age of first implantation had a significant role in the development of communicative-pragmatic ability.

Keywords: developmental pragmatics; communicative-pragmatic ability; hearing impairment; cochlear implant; early intervention

Introduction

Communication is crucial in the lives of individuals because it enables them to share thoughts, knowledge, and feelings with other people, and to create meaning during social interactions. It is a complex ability because it incorporates not merely language, but also many other elements, such as prosodic – e.g., tone of voice, intonation and rhythm – and extralinguistic – e.g., facial expressions and gestures – cues (Bara, 2010). In particular, the ability to use language and other expressive means in a given context is referred to as pragmatics (Levinson, 1983).

Knowing how to communicate appropriately and effectively is therefore essential for daily life. Deaf or hard of hearing (D/HH) children who do not have access to sign language or other forms of communication (Hall et al., 2019) are at risk of receiving less information about natural conversations and social interactions. In light of this, early diagnosis and intervention are critical to help these children access specific language and prevent delayed development of communicative abilities (Toe et al., 2020).

Nowadays – as stated in the Early Hearing Detection and Intervention (EHDI) guidelines and recommended by the Joint Committee of Infant Hearing ("Year 2019 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs," 2019) – children born with permanent profound hearing impairment usually receive a Cochlear Implant (CI), the benefits of which are undeniable as it enhances auditory development.

The literature on the communicative-pragmatic ability of children with CIs has traditionally focused on conversational analysis (Church et al., 2017) and linguistic expressive modality, whereas only recent studies (Ambrose, 2016; Le Maner-Idrissi et al., 2020; Socher et al., 2019) began to address other expressive cues that might accompany the vocal channel, such as gestures and prosody, which are pivotal elements of human multimodal communicative ability (see Bara, 2010; Bosco et al., 2013; Holler & Levinson, 2019).

Children fitted with a CI have been described as able to carry on a conversation with their peers, albeit with some difficulty. For example, Tye-Murray (2003) compared the oral conversational fluency of 181 children (8 to 9 years old) with CIs to that of children with typical auditory development (TA), as they engaged in a conversation with a clinician, and reported that children with CIs spent more time engaging in communication breakdowns (e.g., the speaker says something but the listener does not understand) and silence than their TA peers. Similarly, Paatsch and Toe (2014) investigated spontaneous conversations between 31 school-aged children with D/HH – 20 children fitted with CI and 11 fitted binaurally with hearing aids – and 31 children with TA (8 to 12 years old) and reported that children with D/HH initiated a higher percentage of conversation topics and took longer conversation turns (i.e., words per turn) than their TA partners. In particular, children with D/HH tended to ask more questions and make more personal comments (even if irrelevant). In contrast, children with TA used more conversational devices (e.g., "ooh", "cool") and were more likely to respond with short answers. This suggests that children with D/HH may have developed these strategies to control the topic of the conversation. However, as just mentioned, the sample of the study by Paatsch and Toe (2014) included also participants with hearing aids. Another study by Church et al. (2017) analyzed parts of informal conversations between 10 dyads of children fitted with CIs and TA peers (7;7 to 12;9 years old) and concluded that children with CIs (compared to TA) tend not to ask the speaker to repeat a previous utterance that they did not understand, so, the conversation may not flow smoothly. Howbeit, it should also be considered that the reduced auditory quality (due to the CI) might make conversation in a spoken language more cognitively demanding for children with CIs. In conclusion, literature on conversational ability presents mixed results with some studies reporting similar performance for children with CIs as for their TA peers.

In addition to conversation, other aspects of communicative-pragmatics have been investigated in the literature more recently (e.g., Le Maner-Idrissi et al., 2020; Socher et al., 2019). Regarding gestures, a longitudinal study by Ambrose (2016) found no specific differences in the use of gestural cues between dyads of mother-toddlers with CI (14 months to 3 years old) and toddlers with TA. On the other hand, paralinguistic ability was investigated, for example, in a study by Le Maner-Idrissi et al. (2020). Here, the authors analyzed the ability to comprehend emotional speech in a group of 30 children (age range 5;3 – 13 years) compared to children with TA and found a lower performance in the former group. In a study by Socher et al. (2019), children with CI, compared to children without hearing loss (HL), were found to have differences in non-verbal communication, but not in conversational skills and other pragmatic behaviors, such as greeting others and responding to greetings.

Previous evidence suggests that age at implantation has a significant impact on the development of communicative ability (Colletti et al., 2012; Guerzoni et al., 2016; Hilviu et al., 2021). For example, Yoshinaga-Itano et al. (2017) observed that early intervention has significant benefits for the development of a child's vocabulary skills, which may be comparable to those of their peers. In contrast, Inscoe et al. (2009) reported that age at implantation had no statistically significant effect on the development of linguistic and communicative ability. These results were confirmed by other authors who assessed the pragmatic abilities of school-aged children with CIs and found no significant correlation between age at implantation and pragmatic performance (Most et al., 2010; Socher et al., 2019). However, it should be noted that studies on children with CIs are very heterogeneous and these mixed results could also be due to the different characteristics of the sample, such as limited number of participants or inclusion of children with hearing aids, age at implantation, the length of CI use, inclusion of children with a unilateral CI or with bilateral CIs, speech therapy or use of sign language. Indeed, many children with CIs use multimodal communication (oral + sign language or speechreading) and thus might exhibit different communicative behaviors than children with TA who mainly use only one modality; however, other children with CIs did not have access to other forms of language (e.g., sign language, speechreading) before CI implantation. Thus, the CI provides these children with their first opportunity to be exposed to a specific language and to begin to practice communication in a social context.

These mixed scenarios and inconclusive findings point to the need for in-depth assessments to determine whether, and to what extent, age at implantation and length of access to a particular language influence the development of communicative-pragmatic abilities. Furthermore, to our knowledge, the improvements and benefits associated with CIs have been observed mainly in basic language skills, and most previous studies (Caselli et al., 2012; Church et al., 2017; Nicastri et al., 2014; Paatsch & Toe, 2014; Tye-Murray, 2003) have not specifically considered other aspects relevant in the pragmatic domain, such as extralinguistic and paralinguistic expressive means, appropriateness to the context and compliance with social norms, such as politeness, in a social contexts.

The present study

In the present study we aimed to provide a comprehensive assessment of communicative-pragmatic ability in children with CIs and TA peers by using the Assessment Battery for Communication (ABaCo), a tool for investigating a wide range of communicative aspects expressed through different expressive modalities. ABaCo has been validated for adults

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and (in a modified version) for children (Bosco et al., 2012; Sacco et al., 2008) and normative values were provided for the Italian adult population (Angeleri et al., 2012). ABaCo provides a complete evaluation of communicative-pragmatic abilities in children with typical (Bosco et al., 2013; Bosco & Gabbatore, 2017) and atypical development (Angeleri et al., 2016), as well as in adult clinical populations (Bosco et al., 2017; Parola et al., 2016). Some of the scales composing ABaCo were adapted for English (Davis et al., 2015), Finnish (Gabbatore et al., 2019), Serbian (Dordević et al., 2016) and Portuguese cultural contexts (Agrela et al., 2021). Specifically, we investigated different expressive means, i.e., linguistic, extralinguistic (e.g., gestural and facial expression), paralinguistic (e.g., prosodic), as well as sensitivity to social context and conversational skills. We also examined and compared comprehension and production abilities to explore whether there were specific differences between TA and CI peers in these different modalities.

Finally, we aimed to explore whether the age of cochlear implantation affects the development of communicative-pragmatic abilities. Our sample thus included children who had undergone bilateral cochlear implantation at different ages, and we examined whether the age of first and second implantation could predict the development of pragmatic abilities during the early school years. The children with CIs did not have access to other forms of language (e.g., sign language) and to communication exchanges before CI implantation. Thus, CI implantation provided these children with their first opportunity to be exposed to a specific language and to practice communication in a social context, and the age of implantation corresponds to the length of access to a specific language.

The two main aims of the study are:

I. To test whether there are significant differences in the overall communicative-pragmatic performance in comprehension and production between children with CI and TA peers on the ABaCo.

II. To assess whether there is an effect of age of implantation on pragmatic development, i.e., whether children with early cochlear implantation show better pragmatic performance than children with late implantation.

Methods

Participants

Forty-four children were included in the present study. Twenty-two children (aged between 6;11 years and 9;11 years; 12 females, 10 males; mean age (sd) = 98.64 (11.19) months) were diagnosed with congenital profound hearing loss (> 90 dB; PTA at 0.5, 1, 2, 4 kHz; mean speech recognition dB HL 42.27 (6.85)). Three children present a progressive hearing loss and to assess the influence on the results of including children with progressive hearing loss, we provided additional analysis in **SM1**. All D/HH children had been fitted with bilateral CIs – mean (sd) of first CI operation: 20.68 (18.09); mean (sd) of second CI operation: 34.64 (31.08). They all used oral communication and did not utilize sign language. The mean (sd) hearing level, with the help of CI, at the moment they were tested was 22.16 dB (2.83). See Table 1 for more details on the experimental group, and for the age of first and second implantation for each participant. The children were recruited from the ENT Department of the Martini Hospital in Turin, Italy. Exclusion criteria for all the participants were the presence of neurological disease or neuropsychiatric illness, visual and language impairments. The language impairments were assessed for participants with CI with the Language Evaluation Battery (BVL 4-12; Marini et al., 2015), for TA participants by asking their

Table 1. Information on the experimental sample: children with bilateral Cochlear Implants (CI). Age Range column indicates age in years and months. Abbreviations: CMV = Cytomegalovirus

ID	Age in months	Gender	Etiopathogenesis	Degree	Speech recognition 100% dB HL	Age right CI in months	Age left CI in months
1	83	M	Unknown	Profound	50	14	7
2	83	F	GJB2 mutation	Profound	50	15	72
3	84	F	GJB2 mutation	Profound	50	12	24
4	84	M	CMV	Profound*	50	19	17
5	90	F	Unknown	Profound-to-severe	40	30	38
6	85	F	GJB2 mutation	Profound	40	13	13
7	90	M	GJB2 mutation	Profound	50	12	12
8	91	F	Unknown	Profound*	30	84	96
9	92	F	Hypoxia	Profound	40	28	17
10	92	M	GJB2 mutation	Profound	40	18	18
11	100	M	Unknown	Profound	40	10	10
12	105	M	Unknown	Profound	40	30	30
13	105	F	Unknown	Profound	30	12	12
14	107	M	GJB2 mutation	Profound	40	18	29
15	107	F	Hypoxia	Profound*	50	60	121
16	107	M	Unknown	Profound	50	14	70
17	108	M	GJB2 mutation	Profound	40	12	12
18	108	F	GJB2 mutation	Profound	50	11	19
19	110	F	CMV	Profound	40	12	14
20	111	F	GJB2 mutation	Profound	40	12	12
21	112	M	GJB2 mutation	Profound	40	27	27
22	116	F	Unknown	Profound	30	12	72

*Progressive

school teachers to not include in the sample children with a diagnosed disorder, e.g., Specific Learning Disorders or Language Disorder. The BVL is an assessment battery that evaluates general linguistic skills (such as phonological, lexical, semantic etc.) in children from 4 to 12 years old. For the evaluation, we used the BVL – Semantic Fluency task. The raw scores were transformed into z-scores and the cut-off score, in order to compare participants with the normative values (see SM2), was used. Furthermore, we used the Narrative task of the BVL, which is a multilevel approach to measure language production skills, for assessing if children with CIs and TA peers are comparable on phonological and morpho-syntactic skills (see SM3 and SM4). All children had been through a treatment program, i.e., auditory/verbal program and used oral language.

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The control sample comprised 22 children with TA recruited from local elementary schools (aged between 6;11 years and 9;11 years; 12 females, 10 males; mean age (sd) = 100.00 (12.25) months). All children were native Italian speakers. No significant difference was observed between the group with CIs and the group of TA children in non-verbal intelligence ($t_{(42)} = -.46$, $p = .65$) measured with Raven's colored progressive matrices (CPM).

Both families and children received detailed information about the aims of the research as suggested by the principles of the Helsinki Declaration. Parents or caregivers were requested to sign the informed consent form, and gave permission for the sessions to be video-recorded. The children and their parents were informed that the participation in the study was voluntary and they could interrupt the test at any time without having to give a reason. The research was approved by the Committee of Bioethics of the Azienda Ospedaliera Universitaria – Città della Salute e della Scienza, Turin, Italy (Protocol number 131.410).

Material

Assessment of Communicative-pragmatic ability

All the children were assessed using the Assessment Battery for Communication (ABaCo; Angeleri et al., 2012; Bosco et al., 2012; Sacco et al., 2008). The battery consists of five scales (linguistic, extralinguistic, paralinguistic, contextual and conversational), each of which is designed to evaluate a different aspect of communication with regard to comprehension and production. The protocol is made up of 172 items, which consist of videotaped scenes shown to the participants and face-to-face interactions with the experimenter. Participants are asked to answer some questions to show their understanding of the situation, or to complete an interaction. The first 4 items of the battery were used as a control task to verify that participants were able to clearly comprehend and hear the scenes (accuracy 100%). The instrument is designed for Italian native speakers. Participants' performance is coded off-line by two independent judges who examine the recordings and are not informed about the aim of the research or identity of the participants. All items are evaluated as correct (1 point) or incorrect (0 points). The degree of reliability between the two blind judges was calculated using 28.57% of the sample (randomly extracted from the entire sample) and total score of each scale and subscales. The average ICC measure was .83 with a 95% confidence interval from .77 to .88 ($p < .001$).

The following sections provide a detailed description of each scale.

Linguistic scale

This scale focuses on linguistic aspects of communication and, in particular, it evaluates the comprehension and production of different communicative acts, such as basic communicative acts i.e., statements, questions, requests and commands (Kasher, 1994), standard communicative acts, irony and deceit, using language (Searle, 1975).

- Comprehension: in the case of basic communicative acts, the participant is asked to evaluate the truthfulness of a statement, answer a simple question, perform a requested action, or carry out an order. In the case of standard communicative acts, irony and deceit, the participant watches some short videos in which an actor asks the partner a question and the partner answers. The participant has to

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demonstrate an understanding of the situation and of the answer, by simply answering some questions about the scene.

- Production: in the case of basic communicative acts, the participant is required to produce a statement, a question, a request, or a command. In the case of standard communicative acts, irony and deceit, the participants watch some videos in which an actor formulates a question depending on the context and the participant is asked to answer the question.

Extralinguistic scale

This scale assesses the comprehension and production of communicative acts (i.e., basic communicative acts, standard communicative acts, irony and deceit) using gestures and facial expressions. The tasks are similar to those of the linguistic scale, except for the use of language.

- Comprehension: the participant is required to show an understanding of communicative acts expressed through gestures.
- Production: the participant is required to produce communicative acts using gestures and facial expressions only.

Paralinguistic scale

The scale evaluates the comprehension and production of all non-verbal cues (e.g., prosody) that supplement meaning expressed through linguistic and extralinguistic modalities.

- Comprehension: this subscale includes three types of tasks (i.e., basic emotions, basic communicative acts and paralinguistic incongruity). For basic communicative acts and communicative acts that express emotions, video clips in which an actor speaks an invented language are shown to the participant and he/she is asked to recognize the expressed emotion or to demonstrate comprehension of the basic communicative act that is produced. As far as paralinguistic incongruity is concerned, the participant watches videos in which an actor asks his interlocutor a question, and the latter answers with a sentence that is appropriate to the specific situation, but in which the paralinguistic indicators are contradictory. The participant has to recognize the paralinguistic incongruity.
- Production: this comprises two tasks, i.e., basic communicative acts that express emotions, and basic communicative acts. The participant is asked to produce communicative acts using appropriate paralinguistic aspects, in order to express a basic emotion, a statement, a question, a request or a command.

Contextual scale

This scale assesses the child's ability to use appropriate communicative behaviors with respect to different social contexts.

- Comprehension: the participant has to demonstrate his/her knowledge of the rules that guide communicative interaction in a specific social context. This ability is

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assessed through two tasks: violation of the norms of discourse and violation of social norms. In the first case, the participant must recognize the violation of a Grice's maxim (Grice, 1975) in some of the videos showing an interaction between two actors. In the social violation task, the participant is asked to understand the inadequacy of communicative acts with respect to the social context.

- Production: the participant must produce communicative acts that require a variety of levels of formality or informality.

Conversational scale

This scale evaluates the child's ability to entertain a conversation (with the experimenter), respecting topic, time, content and turn-taking. The examiner engages the participant in four short, free-flowing conversations on a variety of topics, such as leisure activities or summer holidays. (See **SM5** for specific examples of the items in each scale and for a comprehensive description of the items and outcome variables for each scale (see Table S2), and for more detailed information on the ABaCo battery see Angeleri et al., 2012; Bosco et al., 2012; Parola et al., 2020.)

Evaluation of general intelligence

To avoid differences that may be due to overall general intelligence, the Colored Progressive Matrices test was administered (CPM; Raven, 1947) to the two groups (HI and TA). Children had to solve 3 sets of 12 colored puzzles (for a total of 36) by choosing the missing part among six alternatives. CPMs enable evaluation of intelligence based on problem-solving and logical thinking, without involving language ability.

Procedure

All children of both groups (experimental and control) were tested individually (only the examiner was in the same room with the participant). Children with CIs were tested individually in a room at the clinic, while TA children were tested individually in an empty classroom at school. Graduate research assistants in Psychology administered the tests (ABaCo and CPM) in two sessions, each lasting approximately one hour. The ABaCo was administered to both groups with the same identical procedure, i.e., participants were asked to watch the video recorded scenes with the examiner and then to answer some questions to show their understanding of the situation, or to complete an interaction. In case children did not understand or hear an instruction, or part of a video, the examiner repeated it or played the video again. The CPMs were presented in paper format, while the ABaCo test was presented on a laptop. None of the children received any help (i.e., use of loudspeakers). Reading and writing abilities were not involved in these tests. The order of the two tests was randomized.

Data analysis

Statistical analyses were performed using R software and Psycho package (R Core Team, 2013).

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Differences in communicative-pragmatic performance

To investigate differences in pragmatic performance between children with cochlear implants and peers with TA, we used a mixed effects linear model with participants' scores on the ABaCo as outcome, group of participants (two levels: children with CI, TA peers), scale (five levels: linguistic, extralinguistic, paralinguistic, contextual and conversational), and modality (two levels: comprehension and production) as categorical predictors, and varying effects by participants and items. We tested the significance of each predictor and interaction term by performing an analysis of deviance (with type III Wald chi-square test) as implemented in the "car" package in R (Fox & Weisberg, 2011). Post-hoc pairwise comparison with Tukey correction for multiple comparisons was conducted using the lsmeans package in R (Lenth, 2016).

We provided in the supplementary material additional analysis, investigating the effect of age group and of non-verbal intelligence (see **SM6**). Further, to control for the role of linguistic skills, we provided additional analysis including only children with linguistic skills within the normative value, i.e., not below 2 standard deviations from the BVL normative values (see **SM2**). Finally, we provided further additional analysis (see **SM3** and **SM4**) to control for the role of differences between children with CIs and TA peers in basic language skills (phonological and morpho-syntactical) using the Narrative task scores (Marini et al., 2011, 2015; Marini & Carlomagno, 2004) – between the two groups.

Role of the age of implantation on the different ABaCo scales

To analyze the role of the different factors explaining the pragmatic performance of children with cochlear implants on the different scales of the ABaCo Battery, we used a mixed effects linear model with scores on the ABaCo as outcome, separately evaluating the effect of relevant predictors – chronological age, age of first and second implantation (in months), non-verbal intelligence (Raven matrices scores) for each ABaCo scale (linguistic, extralinguistic, paralinguistic, contextual and conversational) – and varying the effects by participants and items. We included relevant predictors using a forward selection procedure, starting from a null model including just chronological age (in months), and then checking at each step whether the addition of each predictor corresponded to a significant increase in goodness of fit using the likelihood ratio test and the Akaike Information Criteria (AIC). Continuous relevant predictors were scaled before being included in the model. The rationale of the procedure was to assess whether the inclusion in the model of each relevant predictor, and of age of first and second implantation in particular, was able to improve the fit of the model and provide a unique contribution in explaining the poorer pragmatic performance of children with cochlear implants, having assessed the role of other relevant factors. This analysis was only performed on the group of children with cochlear implants.

Results

Communicative-pragmatic ability

The analysis revealed a significant effect of *Group* ($\chi^2(1, N = 44) = 18.47, p < .001$). As shown in Table 2, an examination of the main effects of *Group* revealed that in the overall ABaCo performance, children with cochlear implants performed worse than TA peers on the ABaCo as a whole ($\beta = -.17, p < .001$). The analysis also showed a significant effect of *Scale* ($\chi^2(4, N = 44) = 45.27, p < .001$), indicating that children's performance at the whole

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Table 2. Performance obtained by children with cochlear implants (CI) and TA peers on the different scales and on the overall ABaCo battery. In the table are reported the *p*-values for post-hoc tests with Tukey correction for multiple comparisons, and the effect size of the differences (Hedges' g)

Performance on the different scales and on the overall ABaCo battery				
	CI (n = 22)	TA (n = 22)	*p-value*	*Hedges' g*
Overall ABaCo	75.2 (.18)	83.3 (.15)	<.001*	–.55
Linguistic	77.1 (.12)	81 .6 (.13)	.23	–.50
Extralinguistic	71.5 (.16)	74.4 (.15)	.45	–.20
Paralinguistic	70.5 (.19)	82.2 (.15)	< .01	–.76
Contextual	66.9 (.26)	83.1 (.22)	< .01	–.73
Conversational	92.6 (.09)	95.8 (.05)	.45	–.55

*The *p*-value refers to the main effect of Group in the mixed effect linear model.

group level, i.e., children with cochlear implants and TA peers, was significantly different across the different scales of the ABaCo[1]. See Table 2.

The interaction between *Scale* × *Group* was also significant ($\chi^2(3, N = 44) = 20.17$, $p < .001$). Post-hoc pairwise comparisons with Tukey correction revealed that children with CIs (all age groups pooled together) performed worse than TA peers on the paralinguistic ($p < .01$) and contextual scales ($p < .01$), while no significant differences were found on the other scales (see Table 2).

The interaction between *Scale* × *Modality* was also significant ($\chi^2(3, N = 44) = 16.14$, $p = .04$). Looking at the differences in scores on the ABaCo scales for the different sub-scales (two levels: comprehension and production), post-hoc pairwise comparisons with Tukey correction revealed that participants at the whole group level showed a better performance in comprehension vs. production scores in linguistic ($p < .001$) and extralinguistic scales ($p < .001$), and a better performance in production vs. comprehension scores in the paralinguistic scale ($p < .05$). We did not find a significant interaction between *Group* × *Modality* ($\chi^2(3, N = 44) = 1.48$, $p = .22$) or *Group* × *Scale* × *Modality* ($\chi^2(3, N = 44) = 1.82$, $p = .61$), indicating no significant between-groups (CI and TA) differences in comprehension vs. production subscales in the different ABaCo scales or in the overall ABaCO performance (see Table 3).

Role of age of implantation

The analysis revealed a significant effect of non-verbal intelligence (F $\chi^2(5, N = 22) = 29.73$, $p < .001$) and of age of first implantation (F $\chi^2(5, N = 22) = 28.62$, $p < .001$) on overall pragmatic performance in children with cochlear implants. Considering separately children with CI's performance at each single ABaCo scale, we found that earlier age of implantation was associated with better performance on the contextual ($\beta = -.08$, $p < .001$) and paralinguistic scales ($\beta = -.06$, $p < .001$), and that higher non-verbal intelligence scores

[1]The effect of Scale is not particularly informative per se, and for a more comprehensive interpretation of the effect of Scale we invite the reader to rely more on the Scale × Group and Scale × Modality interactions (see Table 2 and Table 3).

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Table 3. Performance obtained by children with cochlear implants (CI) and TA peers in comprehension and production on the different scales of the ABaCo battery. In the table are reported the *p*-values for post-hoc tests with Tukey correction for multiple comparisons, and the effect size of the differences (Hedges' g)

Performance on the different scales of the ABaCo battery				
	Comprehension	Production	*p-value*	*Hedges' g*
Linguistic	82.3 (.08)	76.5 (.16)	< .001	.37
Extralinguistic	78.3 (.11)	67.7 (.17)	< .001	.62
Paralinguistic	74.0 (.14)	78.8 (.21)	< .05	–.22
Contextual	73.3 (.24)	76.7 (.27)	= .40	–.12

were associated with better performance on the contextual scale of the ABaCo ($\beta = .12$, $p < .001$). Adding age of first implantation and non-verbal intelligence to the null model (including age only) improved the likelihood of the model and the AIC given our data. However, adding age of second implantation did not result in any further improvement in the likelihood of the model, and thus the selected model only included age, age of first implantation and non-verbal intelligence among the predictors.

Discussion

In the present research, we conducted a comprehensive assessment of the communicative-pragmatic ability in a group of children with CI and a group of TA peers. We assessed the impact of bilateral cochlear implants on the development of a broad range of communicative pragmatic abilities – linguistic, extralinguistic, paralinguistic, contextual and conversational – in D/HH children and evaluated the relationship between age of cochlear implantation and pragmatic development.

Although previous research has shown that children with CI have difficulty in some communicative-pragmatic tasks (Hilviu et al., 2021; Paatsch & Toe, 2014; Tye-Murray, 2003), most of these studies focused on the assessment of conversational and linguistic skills, overlooking non-verbal/extralinguistic and paralinguistic expressive means, thus not allowing a systematic assessment of all means of expression that can be used to realize the communicative pragmatic ability. Further, few studies investigated the communicative-pragmatic ability in children fitted with bilateral CIs at an early age to determine the impact of early cochlear implantation on the development of pragmatic ability: the results of such studies are inconsistent and inconclusive (Guerzoni et al., 2016; Hilviu et al., 2021; Most et al., 2010; Nicastri et al., 2014; Rinaldi et al., 2013; Socher et al., 2019).

The present study contributed to fill the existing gap in the current literature and disentangle the role of age of first and second cochlear implantation in the development of children's pragmatic ability. We found that children with CIs showed different developmental trajectories compared with their TA peers. Specifically, they showed poorer overall performance on the ABaCo compared with TA peers. This is in line with previous studies showing that D/HH children, even when fitted with a CI, continue to experience some difficulties with social interactions and pragmatic abilities (Rinaldi et al., 2013), particularly when they have not had access to other forms of communication (Hall et al., 2019). For example, Most et al. (2010) found that children at a similar age (6-9 years old)

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with CIs or with hearing aids were able to develop several pragmatic abilities at levels comparable to their TA peers. However, they demonstrated atypical use of certain pragmatic behaviors, such as turn-taking and topic maintenance, more frequently compared to TA children. Nicastri et al. (2014) pointed out that children between the ages of 6 and 14 with a unilateral cochlear implant performed worse on metaphor comprehension compared to their TA peers, whereas no differences were found on tasks assessing discourse inferences. In line with this study, we found that even when children with CIs were able to display pragmatic behaviors, they performed less well than TA peers in different tasks included in the ABaCo, indicating a different developmental trajectory of pragmatic ability.

By focusing on the different scales of the ABaCo, we found significant differences in the performance of children with CIs compared to their TA peers on two scales, i.e., the Paralinguistic and the Contextual scales. The Paralinguistic scale assesses the comprehension and production of those communicative aspects that complement the interaction, such as tone of voice and prosody, and that might convey the speaker's actual communicative intentions. Our findings are consistent with previous research assessing emotional speech comprehension in children with CIs, which suggests that it is difficult for children with CIs to reach the same level as their TA peers due to differences in the quality of auditory input (Le Maner-Idrissi et al., 2020; Panzeri et al., 2021). Indeed, these children have difficulty processing auditory inputs and handling those linguistic elements that are more dependent on auditory processing, such as rhythm or accents (e.g., unstressed bound, free morphemes, see Hammer et al., 2010). Impaired acoustic processing may negatively affect the recognition and production of prosodic (verbal and non-verbal) aspects of conversation, such as the use of the tone of voice to convey emotional aspects, mark relevant information or express different basic speech acts (e.g., questions or orders), which were found to be impaired in the group of children with CIs in the present study. The Contextual scale evaluates the adequacy of a communicative act with respect to the norms of discourse (i.e., Gricean maxims) and social norms of communication. Previous studies have shown that children with CIs are less exposed to conversation than TA peers (see Paatsch et al., 2017). Indeed, analyses of parent-child conversations have revealed that conversations between children with CIs and their parents tend to be more controlled. Parents of children with CIs tend to give their children less time to talk, and such children rarely initiate conversation on their own, reducing opportunities for them to engage in conversations with peers or other adults (Rinaldi et al., 2013). Thus, less exposure to social interactions may partially explain these children's difficulties in recognizing social norms of communication, which are generally learned during communicative exchanges.

Consistent with Ambrose (2016), we found no differences in performance on the extralinguistic scale between children with CIs and their TA peers, indicating that children with CIs are able to develop abilities that do not require processing a linguistic input in a normal range. This finding points to the importance of including alternative expressive modalities in training aimed at promoting the development of linguistic-pragmatic skill (Bosco et al., 2018; Parola et al., 2019). We also found no significant differences in performance on the linguistic or conversational scales, in contrast to previous studies that reported differences between children with D/HH and TA peers in these abilities (Church et al., 2017; Tye-Murray, 2003).

Overall, these results suggest that the delay in the development of pragmatic ability is not uniform across the different scales of the ABaCo, with children with CI showing comparable levels of development to their TA peers in some expressive means but not in others. These results suggest that a comprehensive and articulated assessment of pragmatic ability, realized by several means of expressions, is needed when dealing with children with CIs, to detect strengths and weaknesses in pragmatic skill development, and indicate the importance of tracking developmental trajectories by assessing pragmatic ability at different ages. We found no significant differences between children with CIs and TA peers in the comprehension vs. production subscales of the ABaCo, confirming that the differences between the two groups are present in both comprehension and production.

Another aim of our investigation was to evaluate the effect of age at implantation on pragmatic development. To this end, we included children who had undergone bilateral cochlear implantation at different ages and examined the extent to which the age of first and second implantation was able to predict the development of pragmatic abilities during the early school years. Our result showed that age of first implantation was the best predictor of pragmatic performance in children with CI, even after controlling for the other confounding factors, i.e., level of intelligence and children's age, whereas adding age of second implantation did not further improve the fit of the model. This result indicates that children with CIs who received their implant at an earlier age performed better on the ABaCo. More specifically, we found that age of first implantation is related to the pragmatic performance on the two ABaCo scales for which we found significant differences between children with CIs and their TA peers, i.e., the paralinguistic and contextual scales. This result confirmed that the earlier the children were fitted with the implant, the less difficulty they had in these pragmatic skill, especially considering that oral communication was their only access to social communication and interaction.

This result is in line with previous evidence indicating that age at implantation is a key factor in the development of social conversational abilities (Guerzoni et al., 2016; Tye-Murray, 2003). For example, Nicastri et al. (2014) showed, in a group of 31 children with CIs comparable to those of our study in terms of age and age of implantation, that age at implantation was significantly correlated with the development of different pragmatic skills, such as comprehension of metaphors and implicit meaning. However, other studies have reported different results (Socher et al., 2019). For example, Rinaldi et al. (2013) compared 12 children who received the CI by 12 months of age with 11 children implanted during the second year of life, and found no significant difference in vocabulary size or early grammar skills between the two groups. Inscoe et al. (2009) analyzed the performance of 45 children and found that age at implantation did not play a role in expressive spoken language skills. It should be noted, however, that there are important differences across the different studies reported above in terms of mean age at implantation, implantation modality (unilateral vs. bilateral), rehabilitation therapy (therapy vs. no therapy), the linguistic/pragmatic skills assessed, and children's mean age, and it is thus difficult to make direct comparisons between these studies.

Although the evidence supporting the importance of early implantation is far from conclusive, it does indicate that the age of first implantation is a crucial factor in the development of pragmatic ability, and that early implantation may promote typical communicative-pragmatic development. Future studies should consider this aspect and try to replicate these results.

Furthermore, it should be noted that in addition to the age of implantation, speech therapy also provides a crucial contribution to the development of communicative abilities, especially auditory-verbal therapy which emphasizes linguistic abilities in both comprehension and production (Hogan et al., 2008). Finally, it is noteworthy that prior to CI implantation, children with CIs did not have access to other forms of language (e.g., sign language) and communication exchanges. Thus, CI implantation provided them with their first opportunity to be exposed to a specific language and to practice communication in a social context. Therefore, the poorer overall performance of children with CIs in the ABaCo battery could be due to a combination of factors, such as delayed exposure to a specific language compared with TA peers, reduced participation in social interactions, and lower quality of acoustic input because of the CI. Future studies should better disentangle how each of these factors contributes to a different developmental trajectory of pragmatic abilities in children with CIs – for example, by including children with CIs who have been exposed to a specific language, such as sign language, prior to CI implantation.

A limitation of the present study was the small number of participants. This reduced the statistical power of the analysis and the possibility to detect significant differences. We thus suggest that future studies perform a priori statistical power analysis, which may reduce the risk of underpowered studies and increase the possibility of detecting significant differences. In addition, the present study used only a single task to assess children's language skills, whereas a more comprehensive linguistic battery would have allowed for a more comprehensive comparison of communicative and language skills between the two groups. In addition, our sample included some children who received help at school (from a dedicated teacher), which may have influenced the acquisition of communicative-pragmatic ability. In addition, a longitudinal design would have allowed us to test more specific hypotheses about changes in pragmatic skills over time.

Finally, future studies should include also an assessment of other social skills, such as theory of mind, i.e., the ability to ascribe thoughts, beliefs and desires to one's self and to others (Premack & Woodruff, 1978), to investigate in more detail all the factors responsible for the delayed acquisition of communicative-pragmatic skills in children with CIs. Lastly, the results of this investigation need to be replicated with a larger sample, adopting a more principled design able to track the development of pragmatic abilities over different time points.

Conclusions

To conclude, our results show that bilateral CIs – which promote auditory development in children with CI and provide them with their first opportunity to be exposed to a specific language – are helpful in reducing the differences in pragmatic abilities between D/HH children with CIs and their TA peers. Specifically, children with CIs showed similar responses to TA peers on the ABaCo linguistic, extralinguistic and conversational scales, although some difficulties remain in certain pragmatic aspects such as the ability to deal with paralinguistic cues and sensitivity to social contextual ones. The different developmental trajectory of pragmatic skills is mediated by age at implantation, with children fitted with a CI at an earlier age achieving similar levels of pragmatic performance to their TA peers. Our findings pinpoint the importance of a complete and principled pragmatic assessment in children with CIs to identify their strengths and weaknesses, and to highlight the role of early cochlear implantation, in combination with speech therapy, in contributing to promote typical development of their communicative-pragmatic ability.

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