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Research article

Children with hearing impairment and early cochlear implant: A pragmatic assessment

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ABSTRACT

Extensive research has demonstrated the benefits of cochlear implants (CI) in contributing to improve the linguistic skills of children with hearing impairment; however, few studies have focused on the development of pragmatic ability and its relationship with age of implantation. Pragmatics is the ability to use language in different contexts and its development has crucial implications, e.g., social inclusion and professional attainments. In this study, we conducted a comprehensive assessment of pragmatic ability using the Language Pragmatic Abilities (APL Medea), a battery composed by five different tasks: Comprehension of Metaphors, Implicit meaning, Comics, Situations and Colors Game (a perspective taking task). Eighteen children with early CI, belonging to 3 different age groups (6; 11–7; 11, 8; 0–8; 11 and 9; 0–9; 11 years-old), and twenty-four children with typical development (Control Group) participated to the study. We also investigated how the precocity of CI, i.e., age of first implantation, may affect the pragmatic development.

Globally, children with CI obtained lower scores in the APL Medea battery than typically hearing children. However, focusing on the Medea tasks separately, children with CIs differed from their hearing peers only in Comics and Colors Game tasks. Finally, age of implantation was a moderate but significant predictor of pragmatic performance.

1. Introduction

Hearing loss during the early stages of development may lead to several consequences, among which linguistic deficits are probably the most widespread (Jallu et al., 2017). External auditory inputs are necessary to stimulate language acquisition, especially during infancy when the auditory system is not yet mature (Benasich et al., 2014). Therefore, early hearing screening assumes a crucial role since it enables hearing impairment (HI) to be detected in neonates and paves the way for several interventions (e.g., American Academy of Pediatrics and Joint Committee on Infant Hearing, 2007); such screening includes the application of prostheses, as cochlear implants, and speech therapies.

A Cochlear Implant (CI) is an electronic aid surgically implanted near the cochlea that catches external sounds, transforms them into electric stimulations and transmits these to the auditory nerve producing auditory sensations (Wilson and Dorman, 2008). This device allows children to hear external sounds and their own voice, thus promoting language acquisition that, in certain cases, can reach the typical range. The benefits of CIs are well established in the literature, as shown by numerous studies (Bittencourt et al., 2012; Niparko et al., 2010; Peixoto et al., 2013). Svirsky et al. (2000), for example, evaluated several linguistic skills - such as the complexity of language structure, vocabulary, etc. - in children with hearing impairment before and after cochlear implantation. The authors found that the rate of language development after implantation was higher than that expected for children with HI without implantation and similar to that of typically hearing children.

Furthermore, many authors have pointed out that language acquisition is conditioned by children's early age, at the time of implantation, within a sensitive period for auditory development, as indicated by better performance in several linguistic domains – e.g., receptive vocabulary,

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speech perception, recognition and production - (Baumgartner et al., 2002; Colletti et al., 2012; Dettman et al., 2007; Duchesne and Marschark, 2019; Peterson et al., 2010). Nikolopoulos et al. (2004), for instance, compared the development of grammatical abilities in children who received a CI before the age of four and children who had the device fitted at a later age. Children were tested before receiving their CI and at two follow-up intervals, one three years after implantation and the other after five years. Those who received the implant before the age of four obtained better results than those fitted with one later; moreover, their grammatical comprehension improved with age. The authors explained this improvement as a result of the use of the CI but did not exclude an effect of the children's maturation. Geers and colleagues (2009) also investigated expressive and receptive spoken language abilities in HI children (mean age of 5 years) who received a CI before the age of 5. They reported that children's language outcomes were predicted by several factors such as the parents' education level and children's non-verbal intelligence (evaluated through language-free tasks). This result is supported by other researches showing that early interventions, among which the CI, can contribute to improve also non-verbal intelligence (Hess et al., 2014; Schlumberger et al., 2004), expanding the range of benefits provided by this device. Also Geers and colleagues (2009), showed that the age of implantation is a significant facilitator. Globally, numerous studies underlined the key role of young age at implantation, claiming that this factor predicts children's linguistic performance at a later age (Bruijnzeel et al., 2016; Ruben, 2018; Yoshinaga-Itano et al., 2017). More in detail, data showed that children who receive an implant before the age of 12 months have typical phonological development and achieve significantly better results in linguistic tasks than children who get the implant later (Colletti, 2009; Wie, 2010).

However, while extensive research has focused on the analysis of specific aspects of language, such as phonological and morpho-syntactic skills or word recognition and spelling (Caselli et al., 2012; Colin et al., 2017; Lund, 2016; Moeller et al., 2007), few studies have specifically investigated the development of pragmatic ability in children with CIs. Pragmatics refers to the ability to use language to convey a specific meaning in a given context (Bara, 2010; Levinson, 1983; Morris, 1938). This ability is characterized by several skills (Bates, 1976; Grice, 1989), including for instance, the ability to manage a conversation by maintaining a topic and respecting turn-taking - which has an early development (Casillas and Frank, 2017) - and the ability to use language appropriately on the basis of the partner's characteristics, such as age and social status. Pragmatics also comprises the ability to go beyond the literal meaning of an utterance, for example, understanding metaphors, proverbs and irony, which develop later (Billow, 1975). The development of the pragmatic ability is crucial and may have several implications starting from an augmented participation and inclusion in different social contexts to increased academic success and professional attainments.

The few studies available in the literature found that children with CIs achieved low scores in different pragmatic tasks such as metaphor comprehension (Nicastri et al., 2014) and conversation management (Paatsch and Toe, 2014). Most et al. (2010), investigated the profile of pragmatic abilities among children aged between 6 and 9 years with severe hearing impairment (with CIs or hearing aids) during spontaneous conversations with an adult, and compared their performance to that of typically hearing children. The main differences characterizing the performance of children with HI are related to their inability to use verbal turn-taking consistently and appropriately, i.e., the ability to respond to the interlocutor in a timely manner and add relevant information to the conversational topic. Rinaldi et al. (2013) examined linguistic ability - production of words and sentences - and pragmatic skills - assertiveness and responsiveness in everyday dyadic interactions - in children with CIs aged between 1 and a half and 3 years. The authors used checklists and report questionnaires completed by parents to assess pragmatic abilities in children who had received the CI before the age of 12 months and those who got the implant in their second year of life and compared the performance of the two groups with normative data. Overall, the authors found a delay in the development of linguistic and pragmatic abilities in both groups of children with a CI compared to normative data. The authors explained these differences as a result of early social experiences during child-parent interactions. Parents of children with a CI tend to be more present in the interaction by eliciting explicit requests and not giving the child enough space to propose a topic of conversation and this may lead to atypical development of pragmatic ability (DesJardin and Eisenberg, 2007). In addition, Rinaldi and colleagues did not find any differences between the group of children who received the implant within the first year and those who had it fitted between the first and the second year of life.

However, in contrast with these results, other evidence has shown that very early implantation of a CI, i.e., before 24 months of age, allows children with hearing impairment to develop pragmatic and social abilities comparable to those of their typically hearing peers, demonstrating that interventions based on CI can be highly promising (Guerzoni et al., 2016). Socher et al. (2019), for example, examined the occurrence of several pragmatic behaviors in everyday interactions, e.g., asking for help appropriately and responding to greetings, in school-aged children (most of whom had received the implant before the age of 3), and compared their abilities to those of typically hearing children, finding no significant differences.

Overall, the studies in the current literature have reported mixed findings on the consequences of early CI implantation for the development of pragmatic ability (Guerzoni et al., 2016; Most et al., 2010; Nicastri et al., 2014; Rinaldi et al., 2013; Socher et al., 2019). These different outcomes may be related to variables such as the use of diversified assessment tools, the focus on different pragmatic skills, and the different age of the participants. Furthermore, to the best of our knowledge, only a few studies have investigated the impact of the age of early implantation on pragmatic performance of children with CI belonging to different age groups (Dammeyer, 2012; Toe et al., 2007). Thus, further empirical studies are necessary to assess the effectiveness of an early CI in improving pragmatic ability, and to evaluate the impact of early implantation on the development of pragmatic performance in children at different developmental ages. An early intervention aimed at improvement of pragmatic abilities may have important consequences for the development of effective social skills (e.g., Leonard et al., 2011) and individuals' wellbeing (Haukedal et al., 2018).

1.1. Aim of this study

The present study aims to investigate pragmatic ability in children with hearing impairment who have received an early CI intervention (i.e., before 2 years of age). More in detail, it aims to provide a comprehensive assessment of pragmatic performance in 3 groups of school-aged children (from 6 years and 11 months old to 9 years and 11 months) with hearing impairment and a CI within the second year of life (combined with a speech therapy), compared to those of children of the same age with typical development (Control Group, CG). We hypothesized that children with CI would still exhibit difficulties in the pragmatic domain (especially the youngest group: 6; 11–7; 11). Based on findings from previous studies, these differences will be specifically observable in the ability to understand metaphors (Nicastri et al., 2014), in understanding the dialogical structure of a conversation (Paatsch and Toe, 2014; Tye-Murray, 2003) and in the ability to assume the perspective of other people in order to describe things (Peterson and Siegal, 2000; Toe and Paatsch, 2018). Finally, the present research will analyze the relationship between variables traditionally associated with language development in children with CIs (i.e., chronological age, age at CI, and non-verbal intelligence), and the development of pragmatic skills. In detail, we expect that the age of the (first) early CI will have a role in explaining children's pragmatic performance.

2. Method

2.1. Participants

Forty-two Italian-speaking children from north-west Italy took part in the study. Eighteen children, divided into three age groups (6; 11–7; 11, 8; 0–8; 11, 9; 0–9; 11) represent the experimental group (CI, Cochlear Implant). They had severe-to-profound HI (>70 HL dB) and had received at least one CI before the age of 24 months (see Table 1).

Twenty-four children with typical development, recruited from elementary schools, represent the control group (CG). The two groups of children were matched by age ($t_{(40)} = -.052$; $p = .959$), gender ($t_{(40)} = .261$; $p = .795$) and non-verbal intelligence ($t_{(40)} = -.486$; $p = .629$) (see Table 2 for more details on groups). Children with a CI were recruited from the ENT Department of the Martini Hospital in Turin, Italy. The presence of neuropsychiatric, neurological diseases and visual impairments – assessed by an interview of the treatment physician to children's parents, were considered as exclusion criteria. An additional exclusion criteria was the presence of a linguistic deficit, evaluated with the Language Evaluation Battery (BVL 4–12; Marini et al., 2015), with a cut-off score of -2 SD. All children used oral language and were receiving standard Auditory-Verbal Therapy (AVT; Dornan et al., 2010). Participants and families received detailed information about the aims of the research, in accordance with the principles of the Helsinki Declaration. Both children and families were informed that participation was voluntary and that they were authorized to withdraw their participation to the research at any time. 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) and the children's parents gave their informed consent.

2.2. Material

2.2.1. Pragmatic ability assessment

We administered the *Language Pragmatic Abilities - APL Medea* (Lorusso, 2009), a validated battery developed to evaluate the comprehension and use of verbal language in children ranging in age from 5 to 14 years (normative data for the Italian population are also available for different age ranges). The battery has already been used to assess pragmatic skills in children and young adolescents with CI (Nicastri et al., 2014) and in other clinical populations (Cardillo et al., 2018, 2020). All tasks in the APL Medea battery are presented to children in the form of game.

The battery consists of five tasks:

1. *Metaphors* (M): this task (preceded by a practice trial) evaluates the ability to understand the implicit meaning of sentences going beyond the literal meaning. Eight metaphors are orally presented to the child (i.e., read by the examiner), who has to understand the meaning of each. For example: the examiner reads “Today Mark feels like a lion” and the child has to explain that this is a way to say that Marco feels very strong (the maximum score for this task is 16);
2. *Implicit meaning comprehension* (IMC): evaluates the ability to make inferences on implicit contents about situations. It comprises three short stories that are read to the participant, followed by a set of questions designed to investigate the correct understanding of the situation described in the story. For instance: “My arm hurts a lot” says Michael while lying on the examination table. “Do not worry, now I am going to give you a drug that will make disappear the pain” answers Robert. Subjects are asked then questions about the context where the scene is happening, who are the characters and which is Roberts' profession (the maximum score for this task is 14);
3. *Comics* (C): evaluates the ability to understand conversations in terms of their dialogical structure. The examiner reads four pieces of comics that are incomplete and the child is asked to complete them. For example, in one comic there is a chick that asks to his mother “Mom, can I go outside?” and his mother answers “Yes, but do not be late”. After that, the chick meets a kitten and says “Finally we can see each other!” and the kitten answers “Yes, I wanted to see you!”, then, in the last scene, the chick says something (his speech bubble is empty) and the kitten answers “We can play hide and seek!” (the maximum score for this task is 12);
4. *Situations* (S): evaluates the understanding of sentences considering the relative context. In this task, the examiner reads some stories and then asks the child a simple question to test his or her understanding, or presents some options and the child is invited to choose the most appropriate in relation to a specific context. For instance: the teacher says to John “How is that possible that you are always late?”. The child is then questioned “What do you think John will answer?” (the maximum score for this task is 11);
5. *Colors Game* (CG): evaluates the ability to understand other people's mental representations. The examiner presents the child with a game,

Table 1. Information about participants with Hearing Impairment and Cochlear Implant (CI).

ID	Age Range (year; month)	Age in months	Gender	Age first CI in months	Age second CI in months
1	6; 11–7; 11	83	M	7	14
2	6; 11–7; 11	83	F	15	72
3	6; 11–7; 11	84	F	12	24
4	6; 11–7; 11	84	M	17	19
5	6; 11–7; 11	92	F	17	28
6	6; 11–7; 11	90	M	12	12
7	6; 11–7; 11	92	M	18	18
8	6; 11–7; 11	85	F	13	13
9	8; 0–8; 11	107	M	18	29
10	8; 0–8; 11	105	F	12	12
11	8; 0–8; 11	107	M	14	70
12	8; 0–8; 11	100	M	10	10
13	9; 0–9; 11	110	F	12	14
14	9; 0–9; 11	111	F	12	12
15	9; 0–9; 11	116	F	12	72
16	9; 0–9; 11	117	M	13	26
17	9; 0–9; 11	108	M	12	12
18	9; 0–9; 11	108	F	11	19

explains the rules and describes the material needed. The game is very simple: there is a six-sided dice and in each side of the dice there is a colored dot (2 sides have a yellow dot, one side a green dot, one side a red dot and one side a black dot) or a symbol (a smiley face), two pawns and a cardboard divided into three colored horizontal-sections (starting from below: yellow, green and red). One of the player rolls the dice and based on the result (a color or the symbol) the player can put the pawn in the respective colored section of the cardboard (the black dot indicates that the player must stop for a turn, while the smiley face means that the player can roll the dice twice). The first who reaches the red section of the cardboard wins the game. The examiner and the child play a few matches to make sure the child has understood correctly. The participant is then asked to describe the game to another child who was not present before and who will listen to the recording afterwards without knowing the rules or the material that is needed. The description is then transcribed and analyzed, i.e., the child has to report a series of elements such as needed material, game rules, meaning of the smiley face on the dice, etc. (the maximum score for this task is 15).

The final maximum score of the APL Medea is 68.

2.2.2. Non-verbal intelligence assessment

To evaluate the role of non-verbal intelligence in pragmatic performance, we administered the Colored Progressive Matrices (CPM; Raven, 1947). Children were asked to solve 36 colored puzzles (equally divided into three sets: A, AB, B), by choosing the compatible missing part from six items (five of which are distractors). Each correct answer is given one point. The maximum score for each set is 12 and the total maximum score is 36. No difference was found between the two groups.

2.3. Procedure

Research assistants with a degree in Psychology administered the two tests (APL Medea and CPM) in one single session, lasting approximately 40 min. All children of both groups (CI and CG) were tested individually (only the examiner was in the same room with the participant). Children with CIs were tested at the hospital in a room already familiar to them while children with typical hearing abilities were evaluated at school, in an empty classroom. The APL Medea was presented to both groups in an oral form (the examiner read all items) with the support of material presented in paper format, i.e., drawings. In case children did not understand or hear an instruction, the examiner repeated it. If children appeared tired or distracted, the examiner proposed them a short pause (e.g., asking them if they wanted a glass of water).

2.4. Data analyses

Analyses were performed with IBM SPSS Statistics 26 software.

2.4.1. Pragmatic ability assessment

To investigate the differences in pragmatic performance between the two groups of children (CI vs CG), and how these differences are associated with the children's age group and the type of pragmatic task, we submitted their APL Medea scores to a 2 × 3 × 5 repeated measures ANCOVA, with Group (CI vs CG) and Age (6; 11–7; 11 vs 8; 0–8; 11 vs 9; 0–9; 11) as *between-subjects factors*, and Tasks (Metaphors, Implicit Meaning Comprehension, Comics, Situations and Colors Game) as the *within-subjects factor*. Since we were interested in pragmatic performance, we inserted the CPM raw score as a covariate in order to control for the role of non-verbal intelligence, which is generally a predictor of language ability (Geers et al., 2009; Marini et al., 2008).

2.4.2. Role of age at implantation

To investigate if the age at implantation is a significant predictor for children's general pragmatic ability (APL Medea total score), we ran a hierarchical linear regression analysis on the children in the CI group. Specifically, we controlled for the role of age, gender and Raven's CPM score (Raven, 1947), and entered these in the first step of the model. Therefore, children's *age at implantation* was entered as independent variable in the second step in order to verify whether, keeping under control the previous variables, it represents a significant predictor of pragmatic ability in children with a CI.

3. Results

3.1. Pragmatic ability assessment

Individual performance at the APL Medea tasks of children with CI are presented in Table 3.

The repeated measures ANCOVA showed a main effect of Group ($F_{(1,35)} = 8.723$; $p = .006$; $\eta^2_p = .200$), indicating that participants in the CI group generally performed significantly worse than those in the CG, and a main effect of Age ($F_{(2,35)} = 5 = 1\ .566$; $p = .008$; $\eta^2_p = .241$),

Table 2. Demographic details of the two groups in the total sample.

		CI	CG	*t*	*p*-value[a]
N	6; 11–7; 11	8	10		
	8; 0–8; 11	4	7		
	9; 0–9; 11	6	7		
	Total	18	24		
Gender (F; M)	6; 11–7; 11	4 F; 4 M	6 F; 5 M		
	8; 0–8; 11	1 F; 3 M	3 F; 3 M		
	9; 0–9; 11	4 F; 2 M	4 F; 3 M		
	Total	9 F; 9 M	13 F; 11 M		
Age M (SD)	6; 11–7; 11	86.75 (3.73)	87.60 (4.95)	$t_{(16)} = -.402$	.694
	8; 0–8; 11	104.75 (3.30)	101.29 (4.46)	$t_{(9)} = 1.344$	.212
	9; 0–9; 11	111.67 (3.83)	113.86 (2.54)	$t_{(11)} = -1.233$	.243
	Total	99.06 (12.12)	99.25 (11.90)	$t_{(40)} = -.052$	.959
Non-verbal intelligence CPM	6; 11–7; 11	23.62 (2.56)	23.70 (5.29)	$t_{(16)} = -.037$	.971
	8; 0–8; 11	29.50 (5.92)	28.00 (3.60)	$t_{(9)} = .531$	.608
	9; 0–9; 11	29.16 (3.12)	32.57 (1.62)	$t_{(11)} = -2.526$	**.028**
	Total	26.78 (4.49)	27.54 (5.40)	$t_{(40)} = -.486$	.629

Abbreviations: CI = Cochlear Implant group; CG = Control group; M = mean; SD = standard deviation; F = female; M = male.

[a] Statistically significant p-values (<.05) are shown in bold.

Table 3. Individual performance of children with CI at each task of APL Medea battery.

ID	Metaphors	IMC	Comics	Situations	Colors Game	Total APL Medea
1	2.00	6.50	1.00	5.00	4.00	18.50
2	4.00	1.00	2.00	6.00	4.00	17.00
3	6.00	3.00	6.00	4.00	7.00	26.00
4	3.00	4.00	6.00	1.00	8.00	22.00
5	2.00	4.50	.00	2.00	2.00	10.50
6	.00	8.00	1.00	1.00	8.00	18.00
7	3.00	4.50	.00	3.00	8.00	18.50
8	6.00	6.00	9.00	4.00	6.00	31.00
9	7.00	6.00	2.00	3.00	10.00	28.00
10	4.00	5.50	4.00	2.00	4.00	19.50
11	9.00	9.00	5.00	4.00	10.00	37.00
12	8.00	9.50	5.00	6.00	10.00	38.50
13	10.00	12.50	9.00	8.00	10.00	49.50
14	.00	5.00	6.00	7.00	8.00	26.00
15	4.00	10.50	10.00	8.00	7.00	39.50
16	8.00	11.00	10.00	9.00	11.00	49.00
17	8.00	6.50	8.00	4.00	9.00	35.50
18	2.00	9.00	10.00	2.00	9.00	32.00

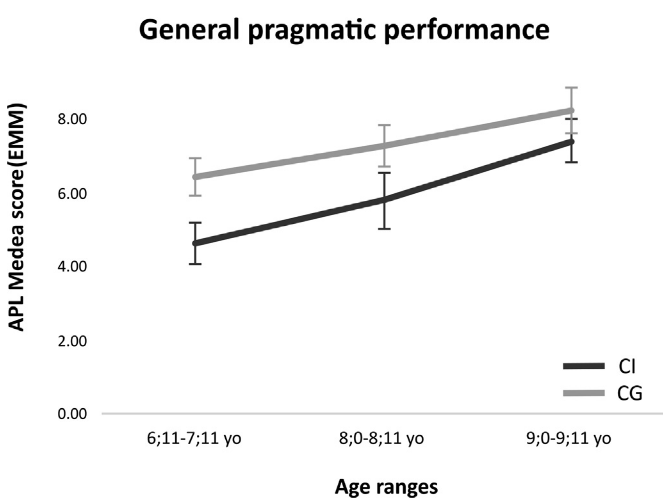

Figure 1. Pragmatic performance. General pragmatic performance (APL Medea score) across the different age ranges in the group of children with a Cochlear Implant (dark grey) and the Control group (light grey). Pairwise comparisons revealed that the only significant difference was found in the 6; 11–7; 11 age range between the Cochlear Implant group and typically hearing children ($p = .012$). N.B. Covariates included in the model were evaluated on the following value: Raven's CPM = 27.214. Error bars indicate standard errors.

indicating that performance improves with age. The effect of APL Medea tasks was not significant ($F_{(4,140)} = .288$; $p = .885$; $\eta^2_p = .008$). The interaction Group*Age*Tasks was significant ($F_{(8,140)} = 2.922$; $p = .005$; $\eta^2_p = .143$) indicating that children's performance on the Medea tasks depends on both the Group and the Age of participants. These effects were significant after controlling for the role of the covariate non-verbal intelligence, i.e., Raven's CPM.

In order to explore the significant interaction Group*Age*Tasks, we performed pairwise comparisons with Bonferroni correction. Considering the different Age groups (three levels: 6; 11–7; 11 vs 8; 0–8; 11 vs 9; 0–9; 11), pairwise comparisons revealed that only children with a CI in the youngest age group (6; 11–7; 11) significantly differed from their hearing peers in terms of overall performance in overall APL Medea tasks ($p = .012$) (see Figure 1).

Considering separately the different Medea tasks (Metaphors, Implicit Meaning Comprehension, Comics, Situations, and Colors Game), children with CIs only differed from their hearing peers (all age groups pooled together) in the Comics task ($p = .008$) and Colors Game task ($p = .018$) (see Table 4).

Finally, considering the different Tasks in the different Age groups, we found that children with a CI differed from their hearing peers in the Age Group 6; 11–7; 11 years in the Colors Game task ($p = .046$), in the Age Group 8; 0–8; 11 in the Comics task ($p = .000$), and in the Age Group 9; 0–9; 11 in the Metaphors task ($p = .014$) (see Figure 2). Overall, pairwise comparisons indicated that the difference between children

Table 4. Means (standard deviations) of the two groups on each APL Medea task and total score.

	CI, *N* = 18		CG, *N* = 24		*p*-value[a]
	Min–Max	M (SD)	Min–Max	M (SD)	
Metaphors	0–10	4.78 (3.08)	2–13	6.42 (2.70)	.080
IMC	1–12.50	6.78 (3.02)	2–12.50	8.25 (2.95)	.124
Comics	0–10	5.22 (3.59)	1–12	7.00 (2.72)	**.008**
Situations	1–9	4.39 (2.48)	1–8	4.96 (1.68)	.431
Colors Game	2–11	7.50 (2.57)	2–15	9.67 (3.06)	**.018**
Total	10.50–49.50	28.67 (11.18)	14–54	36.29 (10.05)	**.006**[b]

P-values indicate the level of significance in pairwise comparisons between the two groups on APL Medea tasks. Abbreviations: CI = Cochlear Implant group; CG = Control group; M = mean; SD = standard deviation; IMC = Implicit Meaning Comprehension.

[a] Statistically significant p-values (<.05) adapted for multiple comparisons with Bonferroni are shown in bold.

[b] Significance level resulting from the ANCOVA analysis.

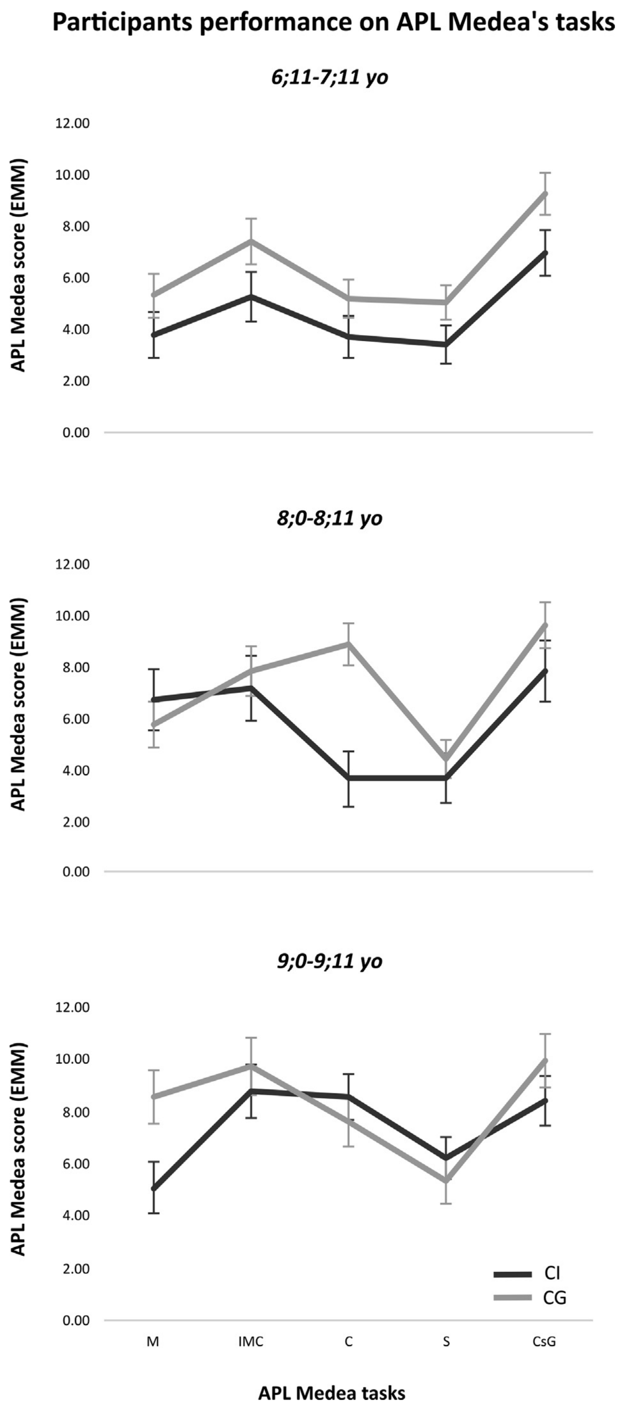

Figure 2. Pragmatic performance in different age-ranges. Scores on APL Medea tasks across the different age ranges in the group of children with a Cochlear Implant (dark grey) and the Control group (light grey). Abbreviations: M = Metaphors; IMC = Implicit Meaning Comprehension; C = Comics; S =Situations; CsG = Colors Game. Error bars indicate standard errors.

with a CI and their hearing peers was greater in the Age group 6; 11–7; 11, but tended to be smaller in the other two groups (8; 0–8; 11 and 9; 0–9; 11). The Medea tasks in which children in the CI group were most impaired compared to the hearing group were Comics and the Colors Game (see Figure 2).

Finally, the effect of CPM was also significant ($F_{(1,35)} = 6.513$; $p = .015$; $\eta^2_p = .157$) indicating an association between non-verbal intelligence and children's general pragmatic performance (both groups, i.e., CI and CG, pooled together).

3.2. Role of age at implantation

The hierarchical linear regression analysis showed a significant impact of age and CPM (see Table 5). More in detail, the R^2 value indicates that age, gender and CPM account for 60% of the variation in pragmatic performance. *Age at implantation* was found to be a significant predictor too: the R^2 indicates that it accounts for an additional 12% of the variation in pragmatic performance (β = −.370; t = −2.363; $p = .034$).

4. Discussion

The present research aimed to study pragmatic ability in school-aged children with a cochlear implant fitted within the first 24 months of life. Firstly, we analyzed their performance on different pragmatic tasks and compared them to a group of typically hearing peers. Overall, children with a CI obtained lower scores in the total of the APL Medea battery compared to typically hearing children. Furthermore, once controlled the role of non-verbal intelligence, the performance of children with CI increased with age.

In order to deeper investigate the role of chronological age and the differences in pragmatic performance between children with a CI and typically hearing peers, we performed a fine-grained analysis across the different age groups (7-, 8- and 9-year-olds). Results indicated that the differences between children with a CI and typically hearing peers in overall pragmatic performance varied across age groups. Indeed, only the younger age group (i.e., 6; 11–7; 11 age range) showed a significant difference while the two older groups (8; 0–8; 11 and 9; 0–9; 11) performed equally to controls. The 8- and 9-year-old children showed substantial differences only in specific tasks, i.e., in the Comics task in the group of 8-year-olds and in the Metaphors task in the 9-year-old age group. This result suggests that since the difference in performance is greater in younger children (7-year-olds), it seems to decrease as age increases. A possible explanation for this result is the major exposure, in terms of time, to the auditory stimuli experienced by older children (see Duchesne and Marschark, 2019; Marschark et al., 2019).

By focusing on the single tasks investigated by the APL Medea - Metaphors, Implicit meaning comprehension, Comics, Situations and Colors Game - the overall performance of children with a CI, was significantly poorer, with respect to the CG, in two tasks only: Comics and Colors Game.

The Comics task evaluates the ability to use pragmatics appropriately in a context, to understand a conversation and to respect its dialogical structure (Lorusso, 2009). Our finding is consistent with previous studies showing that children with a CI have difficulties in mastering a conversation, turn-taking and in recovering from communicative breakdowns (Paatsch and Toe, 2014; Tye-Murray, 2003). We believe this lower level

Table 5. Hierarchical linear regression analysis of children fitted with a Cochlear Implant within 24 months of age ($N = 18$).

Dependent Variable	Predictors	R^2_{Adj}	R^2_{Change}	F_{Change}	Sig. F_{Change}
Pragmatic ability (Tot. score APL Medea)	Model 1	.514	.600	6.990	**.004**
	Model 2	.634	.120	5.582	**.034**

Model 1 (age, gender, and non-verbal intelligence measured by CPM); Model 2 (age at implantation).

of ability may be the consequence of reduced exposure of children with HI to different communicative contexts and partners due to their condition. This may result in difficulty in adopting the appropriate strategy to manage a conversation correctly. Moreover, as other authors have pointed out, this difficulty may also be the result of an inappropriate strategy adopted by this population aimed at controlling conversational turns when they are engaged in conversations (Church et al., 2017; Toe and Paatsch, 2013). This control, which consists, for instance, in choosing the discourse topic or frequently not leaving space for the interlocutor to intervene, helps this population to reduce communicative breakdowns and limit the overuse of communication failure recovery strategies, that could make the linguistic interaction unnatural. An alternative explanation to the delay in mastering conversations could be ascribed to the delay in language development, e.g., vocabulary, as already highlighted by previous research (Rinaldi et al., 2013). The delayed exposure to auditory stimuli can cause a delay in the linguistic acquisition, which in turn supports the pragmatic ability.

The second significant difference we found concerns the Colors Game task, that evaluates children's ability to assume another person's perspective. In literature, this ability is usually connected with the concept of Theory of Mind (ToM; Premack and Woodruff, 1978), i.e., the ability to attribute mental states to the self and to others (Harwood and Farrar, 2006; Taylor et al., 1991). Studies in the literature showed that ToM develops beyond childhood, through adolescence and up to the adulthood (Blakemore, 2008; Brizio et al., 2015). The literature also pointed out a delay in the development of ToM in children with HI (Peterson and Siegal, 2000; Russell et al., 1998). A correlation between pragmatics and ToM is also well documented in the literature (Sperber and Wilson, 2002; Nilsen et al., 2011; Tirassa and Bosco, 2008), even if these two cognitive abilities do not completely overlap (Bambini et al., 2016; Bosco et al., 2018; Bosco & Gabbatore, 2017a, 2017b). Our findings are thus in line with previous studies showing a delay in the developmental trend of ToM in children with HI (Matthews et al., 2018; Meristo and Hjelmquist, 2009; Most et al., 2010). This finding is also in line with previous studies investigating children's expository discourse, i.e., the use of language to describe something or an event (Toe and Paatsch, 2018). The Colors Game task, in this sense, can be considered an example of expository discourse since it requires the child to describe the rules of a game.

A detailed analysis also revealed that the Metaphors task differed significantly only in the 9-year-old children. This task evaluates the ability to go beyond the literal meaning and understand what the partner is really communicating. Our findings are in line with the results of a previous study by Nicastri et al. (2014) showing a difference between children with a CI and hearing peers in the same task. Furthermore, the literature suggests that the ability to understand metaphors develops fully in late childhood (Billow, 1975; Winner et al., 1976). Therefore, it is plausible to assume that the difference we detected in our results is due to a delay in the development of this ability compared to typically hearing peers, rather than a deficit. Additionally, understanding metaphors seems to be linked to other abilities, such as ToM (Lecce et al., 2019), that we also found to be delayed, in a certain way, in our sample of children with a CI.

Finally, we also found a role for the covariate non-verbal intelligence in overall pragmatic performance, in line with previous literature showing that non-verbal intelligence has a significant role in language acquisition (Geers et al., 2009). Despite the important role of IQ, the difference in pragmatic performance between children in the CI group and normal hearing peers is still significant, thus indicating that the pragmatic impairment is specific and not only attributable to the role of non-verbal intelligence.

A further aim of the present study was to investigate the role of age at implantation in pragmatic performance. In our model we first assessed the role of non-verbal intelligence and age as predictors of pragmatic performance, and then added age of implantation as predictor in the second model, to test whether this provides an independent contribution to explain pragmatic performance of children with a CI. Age at implantation was found to be a moderate but significant predictor, confirming the hypothesis that an early CI, as a result of an early intervention, contributes to an improvement in pragmatic ability. Although the time window for CI implantation used in our study was quite short (24 months), it was still possible to observe differences in pragmatic performance depending also on the age of implantation. This result is in line with other findings that underlined the association between age at implantation and pragmatic performance (Guerzoni et al., 2016; Nicastri et al., 2014), but is in contrast with the study by Socher et al. (2019). However, this difference may be due to various variables, such as the data collection procedure. In the study by Socher et al. (2019), in fact, pragmatic measures were provided by parents using rating scales for each pragmatic behavior occurrence and this could have somehow influenced their evaluations.

Our results are encouraging and support previous findings available in the current literature (Guerzoni et al., 2016; Nicastri et al., 2014) that early diagnosis together with concrete support in the form of a hearing device in children who have subsequently also undergone a speech rehabilitation, will help them to limit their pragmatic difficulties in a later age of development.

There are several limitations to the present study. Firstly, the research included a small sample of children with a CI and moreover, the children were not equally divided across age ranges. This might have affected our results, since almost half of the sample were less than 8 years old. A larger and more balanced sample might have helped us to underline differences or similarities between the two groups. Secondly, since this was not a longitudinal study, we were only able to make assumptions about the developmental trend in the pragmatic ability of children with a CI. Future research should investigate pragmatic performance in the same group of children at different time intervals. Thirdly, sociodemographic information was not collected and from previous literature it is well known that several elements intervene during a child's development, such as socioeconomic status or the parents' educational level (Geers et al., 2009) and the presence of siblings (McAlister and Peterson, 2013; Woolfe, 2003). Finally, we did not collect measures on vocabulary, verbal fluency or verbal working-memory, skills that previous literature has shown to be correlated to the pragmatic one (Kronenberger et al., 2018; Marshall et al., 2015; Matthews et al., 2018).

5. Conclusion

Our findings provide evidence in favor of early CI implantation in children with HI. However, early implantation alone is not sufficient to assure typical pragmatic ability development. Our results support findings from previous studies (Guerzoni et al., 2016; Nicastri et al., 2014) providing a more comprehensive evaluation of pragmatics. Globally considered, the existing research suggest that along with early prosthesis, and early verbal and speech rehabilitation (Binos et al., 2021), specialists could also enrich interventions to include programs specifically focused on pragmatic abilities. Indeed, a previous research has shown that the Auditory-Verbal Therapy does not provide a direct effect in improving pragmatic development (Toe et al., 2016). Therefore, programs should be expanded to cover other aspects in which children with a CI appear to have difficulties, such as conversation, perspective-taking and figurative language. Overall, these difficulties have several implications for children with a CI, such as influencing their social interactions by inducing other individuals to interact less with them (Cawthon et al., 2015). Therefore, early conversations with adults (Meristo et al., 2016) and peers are vital for children because in this way they experience natural and diversified forms of interactions and are able to practice pragmatic skills in different contexts. Finally, future research should also include the investigation of other cognitive aspects, as for example ToM, working memory and other expressive means, as non-verbal and paralinguistic ones, in order to understand deeper communicative difficulties in children with CI.

Declarations

Author contribution statement

Dize Hilviu: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Alberto Parola: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Sara Vivaldo: Performed the experiments.

Diego Di Lisi: Contributed reagents, materials, analysis tools or data.

Patrizia Consolino: Conceived and designed the experiments.

Francesca M. Bosco: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

The authors do not have permission to share data.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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