ASK A QUESTION!
HOW ITALIAN CHILDREN WITH COCHLEAR IMPLANTS PRODUCE SUBJECT AND OBJECT *WH*-QUESTIONS

Francesca Volpato[*], Silvia D'Ortenzio[**]

Abstract: Syntax is impaired in individuals with cochlear implants (CIs). Several studies have shown that Italian speaking children fitted with CIs have troubles with relative clauses (Volpato and Adani 2009, Volpato 2010, Volpato 2012, Volpato and Vernice 2014), sentences containing clitic pronouns (Guasti et al. 2014), and *wh*-questions (Volpato and D'Ortenzio 2017). The aim of this study is to provide a detailed analysis of the production of *wh*-questions by a group of 13 Italian-speaking children fitted with CIs, and to compare their performance with a group of 13 typically developing children matched on comparable chronological age. Accuracy is lower in the group of children with CIs than in controls, but no significant difference was found between the two groups. However, much individual variability was observed. Some children with CIs showed good competence of Italian. Other children produce ungrammatical sentences, which is evidence of the linguistic delay associated to hearing impairment, even when they are fitted with CIs.

Keywords: children with cochlear-implants, *wh*-questions, elicited production, Italian

1. Introduction

Sensorineural hearing loss finds its causes in lesions of the cochlea, 8th nerve or central auditory pathways (Bansal 2012). In most of the cases, it is caused by a damage to the hair cells in the cochlea. On the one hand, such injury prevents the correct sound detection, causing a poorer resolution of sounds; on the other hand, sensorineural hearing loss provides an incomplete pattern of activation from the cochlea to the auditory centres of the brain (Kishou-Robin and Boothroyd 2018) causing also an inaccurate processing of the auditory information in the brain (Aimar et al. 2009, Kral and O'Donoghue 2010).

People with sensorineural hearing loss can receive a cochlear implant (CI) only if they satisfy the selection criteria as, for example, an unaided pure-tone average equal to or higher than 90 dBHL, an aided threshold equal to or higher than 60 dBHL, and an absence of speech discrimination and word recognition with appropriate-fitted hearing aids (Geers 2006, Gillis 2018). However, Govaerts (2016) claims that audiometry and speech audiometry, which allow to determine the auditory threshold, are invalid methods for the evaluation of the cochlear function and they could be replaced by psychophysical tests to evaluate the cochlea's capacity for encoding loudness, spectral and temporal content. Moreover, he claims that it would be good practice to include in the selection criteria for CIs further information concerning aetiology and duration of hearing loss, age, the number of surviving neurons, central auditory factors, cognition, motivation, and socio-economic factors (Blamey et al. 2012, Govaerts 2016). CIs are considered "gold

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standard" in the treatment of deafness (Murri et al. 2008) since they enable individuals with severe or profound sensorineural hearing loss to hold conversations easier, be socially stronger, and have better opportunities in their academic career or on the job market (Govaerts 2016).

On the basis of the degree of hearing loss, children can be fitted either with hearing aids (HAs) or CIs. Recent studies (Holt and Svirsky 2008, Niparko et al. 2010, Spencer et al. 2011, Fitzpatrick et al. 2012, Tomblin et al. 2015) have pointed out that the development of language skills is not influenced by the type of device used by the individual rather than external factors such as the higher usage of the device, the higher maternal instruction, the absence of other disabilities (Marname and Ching 2015). CIs are found to have improved speech perception, speech recognition, and oral language skills in children suffering from severe-to-profound hearing loss (Baldassani et al. 2009, Spencer and Marshark 2010). As an example, children fitted with CIs show some linguistic skills, especially those concerned with the lexical domain, comparable to those of normal hearing (NH) age peers in both comprehension and production (Young and Killen 2002, Caselli et al. 2012, Chilosi et al. 2013, Rinaldi et al. 2013). However, in different domains, such as morphology and syntax, the linguistic performance of the children fitted with CIs is not always comparable to those of NH age peers (Young and Killen 2002, Spencer et al. 2003, Geers et al. 2009, Volpato and Adani 2009, Hammer 2010, Volpato 2010, Caselli et al. 2012, Guasti et al. 2014, Volpato 2012, Volpato and Vernice 2014). The children tested by Spencer et al. (2003) showed difficulties in sentence formation, which proved to be short and characterized by a considerable number of grammatical errors. Caselli et al. (2012) found that the lexical and morphosyntactic abilities of a group of Italian-speaking children fitted with CIs were comparable to those of younger hearing children matched on the length of exposure to the language since CI activation. A study focusing on the production of relative clauses (Volpato and Vernice 2014) found that a group of 13 children fitted with CIs performed worse than the age-matched controls.

Although positive or negative results were observed in the various studies when children with CIs were compared to a group to NH age peers, wide variability within the CI group has always been pointed out in children's outcomes. Some children appeared to match NH children's scores on standardized and non-standardized language measures, while others lag well behind age peers. In a longitudinal study, Hay-McCutcheon et al. (2008) tested 30 English-speaking CI children up to the age of 18 years using the Reynell Developmental Language Scales (Reynell 1987), a standardised measure testing receptive and expressive language. Results showed that some children with CIs performed similarly to typically developing children, while others are far below the mean of their age peers. A study investigating 27 French-speaking children fitted with CIs (Duchesne et al. 2009) in their receptive and expressive vocabulary, language, and grammar found that, as a group, they did not differ from their age controls. However, when considering the individual performance, they found that only a small subgroup of children was within the normal range on all linguistic tasks, others were below their age peers on all measures, while other children with CIs performed poorly on some tasks and within normal ranges on others. Szagun (2002) carried out a longitudinal study on a group of 22 children fitted with CIs who were compared to a group of children matched on comparable mean length of utterances (MLU) and found that 10 children showed grammar abilities comparable to hearing children, while 12 children were below the levels of MLU-matched children with NH.

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Focusing on Italian, the area that proved to be among the most problematic for children with CIs is that of complex syntactic structures derived through syntactic movement with word orders in which thematic roles occupy a non-canonical position. Italian-speaking children fitted with CIs significantly differ from NH children in both comprehension (Volpato 2010, 2012, Volpato and Adani 2009) and production (Volpato 2010, Volpato and Vernice 2014) of relative clauses, and in the elicited production of clitic pronouns (Guasti et al. 2014). Similar difficulties with relative clauses and complex syntactic structures were found in different studies testing heterogeneous populations of hearing impaired individuals (either with HA or a CI) across different languages (English: Quigley and Paul 1984, De Villiers 1988, De Villiers et al. 1994; French: Tuller 2000, Tuller and Jakubowicz 2004, Delage and Tuller 2007, Delage 2008; Hebrew: Friedmann and Szterman 2006, 2011, Friedmann et al. 2008, Szterman and Friedmann 2014; Palestinian-Arabic: Haddad-Hanna and Friedmann 2009, Friedmann and Haddad-Hanna 2014; German: Ruigendijk and Friedmann 2017, Penke and Wimmer 2018). In addition to relative clauses, some of these studies also focused on comprehension and production of *wh*-questions and found that these structures are also problematic for individuals with hearing loss, who significantly differ from the age-peer controls (De Villiers et al. 1994, Friedmann and Szterman 2011, Friedmann and Haddad-Hanna 2014, Penke and Wimmer 2017, Ruigendijk and Friedmann 2017). Crucially, *wh*-questions are very frequent in both spoken and written language, in daily communication and in classroom activities, and it is important to test how individuals with hearing loss, and in particular children fitted with CIs, behave with these constructions.

A pilot study on *wh*-questions was carried out on 8 Italian-speaking children with CIs and, differently from the studies conducted on the other languages, it was found that overall, the experimental and the control group show a similar percentage of target sentences produced (Volpato and D'Ortenzio 2017).

Given the importance of these constructions from a pragmatic point of view, this study aims at providing further evidence on the acquisition of *wh*-questions by children fitted with CIs, by testing a larger sample of participants. In addition to raw proportion of target sentences (as in Volpato and D'Ortenzio 2017), this study also reports some statistical analyses in order to determine whether a difference in performance exists between CI and normally hearing (NH) children, thus confirming previous results found in studies investigating more heterogeneous populations with hearing loss. A further aim is to carry out a more in-depth linguistic analysis of the correct and incorrect strategies adopted by all participants, following recent linguistic proposals.

2. Syntactic properties of *wh*-questions

Italian *wh*-questions are characterised by the word order in (1), namely the verb follows the *wh*-element. Like relative clauses, *wh*-questions present a subject-object asymmetry (De Vincenzi 1991, De Vincenzi et al. 1999, Guasti et al. 2012, Del Puppo et al. 2016). While in subject *wh*-questions the canonical Subject-Verb-Object (SVO) order of constituents is maintained (1a), in object *wh*-questions the canonical word order is violated, and the object precedes both the verb and the subject (1b-d).

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(1) a. Chi lava la macchina?
who wash-3SG the car
'Who washes the car?'
b. Cosa ha mangiato Maria?
what has eaten Maria
'What has Maria eaten?'
c. Chi guardano i gatti?
who watch-3PL the cats
'Whom do the cats watch?'
d. Quale maglia lava Gianni?
which-3SG sweater wash-3SG Gianni
'Which sweater does Gianni wash?'

As examples (1b-d) above show, in object *wh*-questions, the subject is located in a post-verbal position and pronounced without any stress. The subject is taken to be marginalized (Antinucci and Cinque 1977, Guasti 1996) in the merge position (Cardinaletti 2001, 2002, 2007) or a low topic position (Belletti 2004).

The *wh*-element can be interpreted either as the subject (2a-3a) or the object (2b-3b) of the sentence, depending on the subject-verb agreement. Sentences like (2a-3a) are subject questions in which the singular verb agrees with the *wh*-operator and the NP in post-verbal position is plural. The sentences in (2b-3b) are object questions, in which the plural verb agrees with the plural post-verbal subject.

(2) a. Chi lava i cani?
who wash-3SG the dogs
'Who washes the dogs?'
b. Chi lavano i cani?
who wash-3PL the dogs
'Whom do the dogs wash?'

(3) a. Quale cuoco saluta i calciatori?
which-3SG chef greet-3SG the football players
'Which chef greets the football players?'
b. Quale cuoco salutano i calciatori?
which-3SG chef greet-3PL the football players
'Which chef do the football players greet?'

Wh-questions are characterised by a dependency between the *wh*-operator in sentence initial position and a gap in the position from which the operator has moved and in which it is interpreted. The landing site of the moved *wh*-element is usually Spec, CP, or a different projection in the CP area (or specFocusP in the more articulated structure proposed by Rizzi 1997). In subject questions (4a-5a), the subject undergoes vacuous movement, as it does not alter the Italian canonical word order (SVO). In object questions (4b-5b), the object leaves a gap in a post-verbal position that follows the subject.

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(4) a. [$_{CP}$ Chi <chi> lava i cani?]
who <who> wash-3SG the dogs
'Who washes the dogs?'
b. [$_{CP}$ Chi lavano <chi> i cani?]
who wash-3PL <who> the dogs
'Whom do the dogs wash?'

(5) a. [$_{CP}$ Quale cuoco <quale cuoco> saluta i calciatori?]
which-3SG chef <which chef> greet-3SG the football players
'Which chef greets the football players?'
b. [$_{CP}$ Quale cuoco salutano <quale cuoco> i calciatori?]
which-3SG chef greet-3PL <which chef> the football players
'Which chef do the football players greet?'

As the examples above show, this dependency is short in subject questions (4a-5a) and is longer in object questions (4b-5b).

As mentioned before, the *wh*-element must be adjacent with the verb. This requirement has been formalized by Rizzi (1996) in terms of the *wh*-criterion:

(6) a. Each *wh*-operator must be in a Spec-head relation with a [+wh] X^0
b. Each [+wh] head must be in a Spec-head relation with a *wh*-operator.

Specifically, the [+wh] feature is generated in I and moves to C together with the inflected verb. Then, the *wh*-operator moves to Spec, CP. As a result of these movements, the verb is in a Spec-Head relation with the *wh*-operator and vice versa, as required by the two clauses of the *wh*-criterion. An example is provided below:

(7) a. Chi lavano i cani?
who wash-3PL the dogs
'Whom do the dogs wash?'
b. [$_{CP}$ chi_j [$lavano_i$ [$_{TP}$ i cani t_i t_j]]]?
[$_{CP}$ who_j [$wash_i$ [$_{TP}$ the dogs t_i t_j]]]?

Note that the interpretation of *who*-questions may be ambiguous if the subject and the object share the same number features and the verb is reversible, namely the arguments of the transitive verb can either be the subject or the object of the sentence. Indeed, subject and object *wh*-questions in Italian present the same order *Wh V SN* as shown by the following examples[1]:

(8) Chi ha attaccato la leonessa?
who has attacked the lioness
Interpretation 1: 'Who attacked the lioness?'
Interpretation 2: 'Whom did the lioness attack?'

[1] Examples are taken and adapted from De Vincenzi (1991).

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Taken out of context, the question in (8) has two interpretations, it is either a subject *wh*- or an object *wh*-question. Therefore, the *wh*-element *chi* 'who' can be interpreted as the subject or the object of the verb. However, the question in (8) can be disambiguated by resorting to the linguistic-pragmatic context, as shown by examples (9a-b):

(9) a. Chi ha attaccato la leonessa, per difendere il turista? (Subject)
who has attacked the lioness to defend the tourist
Who has attacked the lioness, to defend the tourist?
b. Chi ha attaccato la leonessa, per difendere i cuccioli
who has attacked the lioness to defend the little ones
di leone? (Object)
of lions
'Whom did the lioness attack, to defend the little lions?'

(9a) is interpreted as a subject question, because a lioness may attack a tourist during a safari, and (9b) is an object question, because the lioness protects her puppies.
Ambiguity effects can also be prevented when the *wh*-element and the post-verbal NP have different number features. This is more evident with *which*-phrases in Italian, because they can be either singular or plural, as the following examples show:

(10) a. Quale leone tira i bambini? (Subject)
which-3SG lion pulls the children
'Which lion pulls the children?'
b. Quale leone tirano i bambini? (Object)
which-3SG lion pull-3PL the children
'Which lion do the children pull?'

In Italian, several strategies are available when a *wh*-question must be produced.
Sometimes, the subject can be found in a left dislocated position before the *wh*-element (11). Prosodically, this question is pronounced with a short pause between the subject and the *wh*-element, which is represented by a comma in written texts. Thus, the subject forms a prosodic unit (Guasti et al. 2012, 2015, Belletti and Guasti 2015)[2]:

(11) I cani, chi lavano?
the dogs, who wash-3PL?
'Whom do the dogs wash?'

[2] Differently from other languages (such as English), in Italian object questions, the DP subject cannot occur between the *wh*- operator and the verb: **chi i cani lavano?* who the dogs wash.3pl 'Whom are the dogs washing?'.

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Since Italian is a *pro-drop* language[3], it is possible to utter a *wh*-question with a null subject if the pragmatic conditions are met (12a). Moreover, it is obligatory to resort to a null subject with first and second person (12b):

(12) a. Chi lavano (i gatti)?
who wash-3PL (the cats)
'Whom do the cats wash?'
b. Chi (tu) guardi?
who (you) look-2SG
'Whom do you look at?'

Italian spoken language also allows the possibility to express a *wh*-question by resorting to a cleft structure as in (13)[4]. In this structure, the subject can occur in either pre-verbal or post-verbal position. This last condition is considered more natural (Belletti and Guasti 2015).

(13) Chi è che (i cani) lavano (i cani)?
who is that (the dogs) wash-3PL (the dogs)
'Whom are the dogs washing?'

3. Studies on the acquisition of *wh*-questions in populations with hearing loss and with typical language development

Previous studies on the acquisition of *wh*-questions in Italian have pointed out that children master *wh*-questions with *cosa* (what) or subject *chi* (who) and characterized by the presence of irreversible verbs starting from the age of 2;0, age at which the adjacency requirement between the *wh*-element and the verb is also set properly (Guasti 1996, De Vincenzi 1999).

Later studies investigating the comprehension and production of subject and object *wh*-questions introduced by *chi* 'who' and *quale* + NP 'which' and including reversible verbs (De Vincenzi et al. 1999, Guasti et al. 2014, Del Puppo et al. 2016) have shown that 5;0-year-old children show an asymmetry between subject and object *wh*-questions, namely the former are more easier than the latter. This asymmetry is less evident in 10 to 11-year-old children, who show 80% of accurateness in the production of object *wh*-questions. Furthermore, children showed an asymmetry between *who* and *which* + NP questions, the latter being harder than the former (De Vincenzi et al. 1999). Guasti et al.

[3] *Pro* subjects are found in certain languages, since they are not universal properties. In Italian the use of a *pro* subject is allowed by the richness of the verb inflection, through which is possible to identify an empty category in the subject position (Haegeman 1994).

[4] Poletto (1993) observes that in standard Italian the cleft structure is limited to certain pragmatic contexts (e.g. when the interrogation is on a well-known set of objects or in echo contexts). However, in the northern variety of Italian, the cleft structure does not require any presupposition and is commonly used in spoken language.

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(2012) investigated the production of *wh*-questions in a group of 35 young children aged 4-to-5 years and found that they produce high percentages of subject questions (88% *who*-questions; 80% *which*-questions), but the percentage of object questions is lower (71% and 73%, respectively). Even at an older age (6;0-9;0 years), object questions show lower percentages of occurrence than subject questions (Del Puppo et al. 2016). In adults' production, *wh*-questions introduced by *who* are almost at ceiling (98% for subject questions and 93,5% for object questions), while for *which*-questions lower percentages of accuracy are observed (83% for subject questions and 85% for object questions). Various strategies are adopted when object questions are targeted, all of which are correct and appropriate for the context. Beyond the structure with the post-verbal subject, the structure with left-dislocation of the subject and with a null-subject are employed (Guasti et al. 2012).

In populations with hearing impairment, the acquisition of *wh*-questions is delayed since they have difficulties understanding and producing complex syntactic structures containing long-distance dependencies. Several studies on children with hearing loss and fitted with HAs or CIs have pointed out lower performances of this population compared with the performance of typically developing (TD) children (English: Quigley et al. 1974; German: Ruigendijk and Friedmann 2017, Penke and Wimmer 2018; Hebrew: Friedmann and Szterman 2011; Palestinian-Arabic: Friedmann and Haddad-Hanna 2014; Italian: Volpato and D'Ortenzio 2017). However, children with hearing loss show the typical asymmetries between subject and object questions, namely the former structures are more preserved than the latter, and between *who*- and *which*-questions, i.e. subject and object *who*-questions are easier than subject and object *which*-questions.

Volpato and D'Ortenzio (2017) carried out a pilot study on the production of *who* and *which* + NP questions in a group of 8 Italian-speaking children fitted with CIs. The experimental group (CI group) was compared with a control group composed of children with NH matched on similar chronological age. In this study, only raw proportions of target sentences are presented, from which a similar trend appears to occur in the sentences produced by children with hearing impairment and children with NH. In both groups, the proportion of target subject questions is higher than that of object *wh*-questions, and the proportion of *who* questions is higher than that of *which* + NP questions. As pointed out by previous studies, high individual variability between participants is observed, namely for some of them the number of target *wh*-questions was similar to their NH peers, while some participants still show a problematic production of these structures. In particular, children with CIs produced more ungrammatical sentences than controls (CI: 0,15; NH: 0,07).

4. The experiment

In this section, the experimental and the control groups, the task for the elicitation of *wh*-questions (Guasti et al. 2012), and the response coding will be described.

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4.1 Participants

The experimental group is composed of 13 children with prelingual hearing impairment and fitted with a CI (CI group) ranging in age from 7;5 and 13;10 (mean age: 9;4). Twelve participants suffer from bilateral sensorineural hearing loss, and one from bilateral mixed hearing loss. The participants were born to hearing parents and are hearing impaired since birth. They were diagnosed and fitted with hearing aids (HAs) in a period comprised between birth and 3;6 years. The participants received the CI between 0;7 and 7;8 years, therefore their experience with the CI varies between 1;2 and 10;9 years. Only one participant receives a monaural stimulation through a CI. Twelve participants are binaurally stimulated, since they are fitted with a CI and a contralateral HA or a CI. The participants have only been exposed to oral language. Seven participants follow a speech therapy, while six participants have recently stopped it. All participants have been trained orally. None of them knows or uses any sign language. The participants come from several regions of Italy. The participants were selected and tested at the Ear-Nose-Throat Clinic (ENT Clinic, henceforth), Department of Neurosciences, University of Padua.

The following table summarises personal and clinical data of the CI group:

Table 1. Personal and clinical data of the CI participants. The "*" marks that some data are missing (HL = hearing loss; CI = cochlear implant; HA = hearing aid; HE = hearing experience; S = stimulation; CS = contralateral stimulation; ST = speech therapy; SN = sensorineural; M = mixed).

ID	Age	HL type	Age of HA	Age of CI	Length of HE	Length of use of CI	Type of S	CS	ST	Area of provenance in Italy
EN	7;5	SN	birth	0;7	7;5	6;10	Bilateral	CI	No	North
CO	8;4	SN	*	1;1	*	7;3	Bilateral	CI	No	North
AT	9;0	SN	3;6	6;10	5;6	2;2	Bilateral	HA	Yes	North
MM	9;9	SN	0;6	2;8	9;3	7;1	Bilateral	CI	Yes	North
FZ	10;10	M	2;6	5;7	8;4	5;3	Bilateral	HA	No	Central
RB	9;10	SN	*	7;8	*	2;2	Bilateral	HA	No	North
SV	7;8	SN	*	1;2	*	6;6	Bilateral	CI	Yes	North
VZ	7;10	SN	0;2	1;6	7;8	6;4	Monolateral	No	No	North
MS	10;0	SN	0;5	1;2	9;7	8;10	Bilateral	HA	Yes	North
NV	8;1	SN	0;4	2;7	7;9	5;6	Bilateral	CI	Yes	North
FP	13;10	SN	*	3;1	*	10;9	Bilateral	CI	Yes	Central
ER	8;6	SN	0;6	0;11	8;0	7;7	Bilateral	CI	No	Central
AM	12;8	SN	3;0	4;6	9;8	8;2	Monolateral	No	Yes	North

The results of the children fitted with CIs were compared with those of 13 typically developing normal hearing children of comparable chronological age (NH group). NH children ranged in age from 7;0 to 13;3 years (mean age: 9;3) and came from several regions Italy. The following table presents the main data about the NH group:

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Table 2. Personal data of the NH participants.

ID	Age	Area of provenance in Italy
GM	9;6	South
CL	7;0	North
SA	10;11	North
AO	7;10	North
AR	7;2	North
PN	9;5	North
NL	7;1	North
AL	9;11	North
GD	13;3	Central
AD	8;3	Central
FV	9;7	Central
SB	7;10	Central
FS	12;1	Central

4.2 The task for the elicitation of *wh*-questions

The participants were administered the elicited production task developed by Guasti et al. (2012). The test includes 24 items, investigating the use of subject and object *who* and *which* questions, with six items for each condition. The four conditions are summarised in the following table.

Table 3. Experimental design: conditions

Question type	*Wh*-element	Test items
Subject	Who	*chi acchiappa gli gnomi?*
		who catches the gnomes?
	Which	*quale gatto lava le scimmie?*
		which cat washes the apes?
Object	Who	*chi sporcano gli elefanti?*
		who the elephants dirty?
	Which	*quale cane leccano i gatti?*
		which dog do the cats lick?

For this task, 18 transitive reversible verbs, such as *bite*, *dirty*, *wash*, were used. The use of transitive reversible verbs prevents the child from deriving the meaning of the sentence by relying on semantic or pragmatic cues, since being semantically reversible, these verbs can be compatible with both nouns as agents and patients. *Who*-subject questions always contain a singular verb, and *who*-object questions contain a plural verb. The following picture shows an example of an item used for the elicitation of a subject *who*-question:

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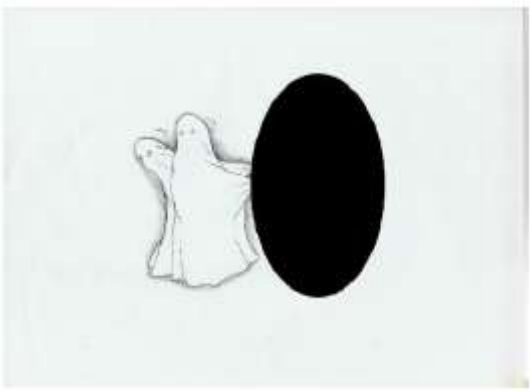

Fig. 1. Picture eliciting a subject who-question

When fig.1 was shown to the participant, the experimenter described the picture 'Someone catches the ghosts. Ask your mum/dad who'. The target sentence was 'Who catches the ghosts?'.

As for *which*-questions, three items eliciting subject questions have singular verbs (Which cook greets the football players?) and three contain a plural verb (Which witches wet the man?); three object questions have singular verbs (Which cows does the horse chase?) and three have a plural verb (Which child do the smurfs dream of?).

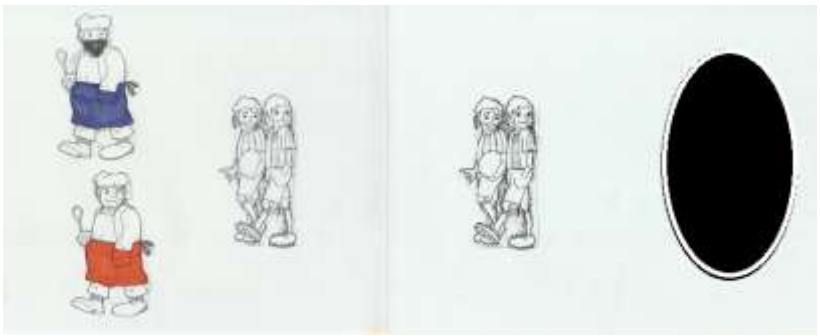

Fig. 2. Picture eliciting a subject which-question

For the item in fig. 2, the picture on the left was shown first, and the experimenter introduced the characters 'There are a cook with a blue apron, a cook with a red one, and two football players'. When the picture on the right appeared, the experimenter described it 'One of the cooks greets the football players. Ask your mum/dad which cook.'. The expected answer was "Which cook greets the football players?".

The participants were assessed in a quiet room of the ENT Clinic. While in Guasti et al. (2012, 2015), the participants heard the stimuli by a recorded voice and then they were asked to ask a question to a puppet, for this study all participants received the stimuli directly from the experimenter. In this way, hearing impaired children could also rely on lip reading. Before assessing the children with CIs, their voice perception was evaluated by the speech therapists through an audio-perceptual test administered by the

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speech therapists with conversational tone and their mouth hidden by their hand. Only children who provide a rate of correct answers equal to or higher than 90% were tested on the production of who and which + NP questions. The children were asked to ask a question to their parents, who did not know the correct answer and had to guess pretending to be magicians.

The task was presented on a laptop computer screen, and the stimuli were displayed through a Power Point presentation. The questions produced by the participants were audiotaped and transcribed by one of the experimenters.

4.3 Response coding

This section presents the way in which the participants' responses were coded.

Both subject and object who- and which-questions were considered correct when they showed the word order Wh V NP (14) or when a cleft structure was produced (15):

(14) a. Chi acchiappa i fantasmi? (Subject question)
who catch-3SG the ghosts
'Who catches the ghosts?'

b. Chi colpiscono i bambini? (Object question)
who hit-3PL the children
'Whom do the children hit?'

(15) a. Quale gatto lava le scimmie (Subject question)
which-3SG cat wash-3SG the apes
'Which cat washes the apes?'

b. Quale gatto lavano le scimmie? (Object question)
which-3SG cat wash-3PL the apes
'Which cat do the apes wash?'

As for object questions, responses were considered grammatically and pragmatically correct when the subject DP was topicalized (16), when the subject was not expresses (17), or when a passive *wh*-question was produced (18):

(16) I bambini, chi colpiscono?
the children, who hit-3PL?
'Whom do the children hit?'

(17) Chi colpiscono?
who (they) hit-3SG
'Whom do the children hit?'

(18) Chi è colpito dai bambini?
who is hit by-the children
'Who is hit by the children?'

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Some children produced questions in which the *wh*-element *which* was replaced by *che* "what" (*che* + NP):

(19) Che grilli legano l' ape?
what crickets tie-3PL the bee?
'What crickets tie the bee?'
TARGET: quali grilli legano l' ape?
which crickets tie-3PL the bee
'Which crickets tie the bee?'

Since this strategy is common in Italian in the oral/colloquial language, the response was considered correct.

We analysed as incorrect some questions that were grammatically correct, but pragmatically infelicitous, as for instance sentences targeting a *which*-question, but introduced by the element *who* (20) or questions with thematic roles inversion (21):

(20) I gatti, chi leccano?
the cats, who (they) lick-3PL
'The cats, whom do they lick?'
TARGET: Quale cane leccano i gatti?
which-3SG dog lick-3PL the cats
'Which dog do the cats lick?'

(21) Che cuoco salutano i calciatori?
what cook greet-3PL the football players
'What cook do the football players greet?'
TARGET: Quale cuoco saluta i calciatori?
which-3SG cook greets the football players
'Which cook greets the football players?'

Other strategies that were coded as incorrect included *in situ wh*-questions (22) and *wh*-questions containing a resumptive clitic pronoun (23):

(22) La fatina tira quali bambini?
the fairy pulls which-3PL children
'The fairy pulls which children?'

(23) Quale cane i gatti lo stanno leccando?
which dog the cats him.CL are licking
'Which dog are the cats licking?'

Some children also produced incomplete or ungrammatical sentences (*quale cuoco?* 'which cook?'). This category includes structures that are not grammatically correct (24), questions containing only the (complex) *wh*-element (25), incomplete sentences (26), and sentences that consists in the repetition of the last part of the stimulus read by the experimenter (27):

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(24) Quali cavalli insegue i leoni?
which-PL horses follow-3SG the lions
'Which horses follows the lions?'
(25) Quale cuoco?
which cook
'Which cook?'
(26) Un bambino fa qualcosa …
a child do-3SG something
'A child makes something …'
(27) Qualcuno acchiappa i fantasmi, chi è?
someone catch-3SG the ghosts who is
'Someone catches the ghosts, who is it?'

5. Results

The following table shows the number and raw proportion of correct responses provided by each group in each condition:

Table 4. Number (No.), proportion of raw scores (Mean), and standard deviation (SD) of correct responses for each group (SQ = subject question; OQ = object question)

		CI			**NH**		
		No.	Mean	SD	No.	Mean	SD
WHO	SQ	61/72	0.85	0.36	67/72	0.93	0.26
	OQ	58/72	0.81	0.40	59/72	0.82	0.39
WHICH	SQ	55/72	0.76	0.43	63/72	0.88	0.33
	OQ	44/72	0.61	0.49	56/72	0.78	0.42
TOTAL		**218/288**	**0.76**		**245/288**	**0.85**	

Given the categorical (dichotomic) nature of the collected data, repeated measure logistic regression analyses in a mixed model were carried out in which a model including the predictor is contrasted against a model without it using a χ^2-test (Jaeger, 2008). All analyses were carried out using the statistical software R (R Development Core Team 2018, R Version 3.5.0)[5]. First, an analysis was carried out in which the independent fixed factors were GROUP (CI vs. NH), SENTENCE TYPE (Subject

[5] In much psycholinguistic research, ANOVAs have been frequently used for the analysis of categorical data. However, as pointed out by Dixon (2008) and Jaeger (2008), the use of ANOVAs for categorical outcomes can lead to incorrect interpretations of results and the use of mixed logit models is more reliable. The advantage of using such models is twofold. On the one hand, they overcome the problems arising from the use of accuracy data transformed into proportions, which causes a loss of information as for the number of observations that contribute to the proportion (Baayen 2008). On the other hand, also random subject and item effects are included in the model (Baayen et al. 2008, Jaeger 2008), thus allowing simultaneous analyses of both experimental fixed effects and individual and/or item (random) differences associated with them. Gelman and Hill (2007) pointed out that mixed models are robust against normality violations.

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Questions vs. Object Questions), and *WH*-OPERATOR (Who vs. Which). Response ACCURACY was the dependent variable. Random factors were SUBJECT and ITEM. The variable GROUP did not contribute to the fit of the model ($\chi^2(1) = 1.7811$, $p < .182$). Hence only the SENTENCE TYPE and *WH*-OPERATOR variables were considered. Estimated coefficients, standard errors, Z-values and associated p-values for the SENTENCE TYPE and *WH*-OPERATOR factors are summarized in Table 5:

Table 5. Estimated coefficients, standard errors, Z-values and associated p-values for the sentence type and *wh*-operator factors

	Estimate	**SE**	**Z**	**p**
Who-Which: *who*	0.8217	0.2562	3.207	p = .001
Subj-Obj: subj	0.8831	0.2574	3.431	p < .001

Overall, as indicated by the coefficients reported in Table 5 an asymmetry between *who*-questions and *which*-questions is observed, namely the former type is significantly more accurate than the latter. In addition, a significant difference is observed between subject questions and object questions, namely the former sentences are more accurate than the latter. By carrying out analyses within each group, we found that within the CI group, a significant asymmetry is found between *who*- and *which*-questions (Wald Z = 2.908, p = .004), while the difference between subject and object questions is only marginally significant (Wald Z = 1.918. p = .055). Within the NH group, no significant difference is observed between *who*- and *which*-questions, whereas a significant difference is observed between subject and object questions (Wald Z = 2.545, p = .011).

In addition, other analyses were performed, in which the SENTENCE CONDITION factor (subject *who*-questions, object *who*-questions, subject *which*-questions, object *which*-questions) was investigated. This variable was found to significantly contribute to the model fitting ($\chi^2(3) = 15.74$, $p = .001$). Estimated coefficients, standard errors, Z-values and associated p-values for the Sentence Condition factor are summarized in Table 6:

Table 6. Estimated coefficients, standard errors, Z-values and associated p-values for the sentence condition factor

	Estimate	SE	Z	P
OVERALL				
Subj.*Who* - Obj.*Who*	−0.8095	0.3936	−2.057	.04
Subj.*Who* - Subj.*Which*	−16.829	0.3809	−4.418	<.001
Subj.*Which* - Obj.*Which*	0.9355	0.3351	2.792	.005
Obj.*Who* - Obj.*Which*	0.8733	0.3322	2.629	.009

By contrasting the 4 different conditions, overall, subject *who* were significantly more accurate than object *who*-questions and subject *which*-questions, subject *which* were significantly more accurate than object *which* questions, and object *who* were significantly more accurate than object *which*.

The same analysis was run within each group. Within the CI group, significant differences were found between subject and object *which*-questions (Wald Z =2.191,

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p = .028), and between object *who*- and object *which*-questions (Wald Z = 2.817, p = .005), but not between subject and object *who*-questions (Wald Z = −0.726, p = .47) and between subject *who*- and subject *which*-questions (Wald Z = −1.389, p = .165). Within the NH group, a significant difference was only found between subject and object *who*-questions (Wald Z = 2.191, p = .028), but not when contrasting the other conditions (subject *who* vs. subject *which*, Wald Z = −1.288, p = .20; subject *which* vs. object *which*, Wald Z = 1.677, p = 0.093; object *who* vs. object *which*, Wald Z = 0.670, p = 0.502).

Several strategies were adopted by the participants of each group. Some strategies were grammatical and appropriate in the context, while some others were considered incorrect. The following table summarises the different correct strategies adopted by each group and show the percentages of accuracy when *who*- and *which*-questions were targeted:

Table 7. % of use of the different correct strategies in each group for each question type (SQ = subject question; OQ = object question)

	CI				**NH**			
	WHO		***WHICH***		***WHO***		***WHICH***	
	SQ	**OQ**	**SQ**	**OQ**	**SQ**	**OQ**	**SQ**	**OQ**
***Wh* V NP**	68%	44%	63%	25%	74%	56%	75%	46%
Topicalized	0%	22%	0%	8%	0%	13%	0%	3%
Cleft	15%	3%	1%	3%	18%	6%	0%	0%
No argument	0%	4%	0%	1%	0%	6%	3%	1%
Passives	0%	4%	0%	14%	0%	3%	0%	18%
***Che* + NP**	0%	1%	6%	8%	0%	0%	8%	10%
Other Right	1%	1%	7%	1%	1%	0%	1%	0%

The strategy with the highest percentage of occurrence is the production of a question with the *Wh* V NP word order under all sentence conditions. The trend is the same for both groups: subject questions show higher percentages than object questions. The condition with the lowest percentage of occurrence is the object *which*-question, for both groups. However, for the CI group percentages are lower than for the NH group (mean % of occurrence: 50% for CI, 63% for NH).

Cleft sentences are produced at lower percentages than *wh*-questions with a final NP for both groups (mean: 6% for both groups). While this strategy is used by children with CIs when both *who*- and *which*-questions were targeted, NH children used it only with items eliciting *who*-questions.

In the items eliciting object questions, the second strategy adopted by children with CIs consists in the production of topicalized sentences (mean percentage 8%), while NH children used it only in the 4% of productions. For both groups, this strategy is mainly used with *who*-questions.

The strategy involving the presence of the passive voice is preferred in the case of *which*-questions by both groups. In a very low percentage of items, both groups replaced the target forms *who* and *which* with the form *che* + NP '*what* + NP'. This percentage is

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slightly higher in the CI group (3%) than in the NH group (1%). While in the former group, this strategy is found in all conditions, in the latter group, it is only found in the subject questions.

By running a between-group analysis in the use of the various correct answering strategies, no significant difference has been found between CI and NH children. In the following table the different incorrect strategies adopted by each group are summarised when *who*- and *which*-questions were targeted:

Table 8. % of use of the different incorrect strategies in each group for each question type (SQ = subject question; OQ = object question)

	CI				**NH**			
	WHO		***WHICH***		***WHO***		***WHICH***	
	SQ	**OQ**	**SQ**	**OQ**	**SQ**	**OQ**	**SQ**	**OQ**
Other *wh*-	0%	0%	1%	8%	6%	7%	7%	11%
Ungrammatical/ uncomplete	4%	4%	13%	18%	1%	7%	6%	6%
Theta inversion	4%	1%	6%	1%	0%	3%	0%	3%
In situ	0%	0%	0%	1%	0%	0%	0%	0%
Clitic pronoun	0%	0%	0%	1%	0%	0%	0%	0%
Other strategies	7%	14%	4%	8%	0%	1%	0%	3%

The type of incorrect production that was most frequent in the CI group is the ungrammatical/incomplete sentence. It was mainly found when *which*-questions were targeted. In the CI group, these productions were significantly higher with items eliciting *which*-questions than *who*-questions ($p = 0.010$). An incorrect strategy that differentiates the two groups is the use of theta-roles inversion. Even though the percentages of occurrence are very low in both groups (mean: 3% in the CI group and 1% in the NH group), in the NH group this strategy is found only with object questions, while in the CI group, it is found especially with items eliciting subject *wh*-questions and to a lower extent in object questions. An incorrect strategy largely used by NH children consists in the production of *wh*-elements different from the target ones (*che bambino sognano i puffi?* 'what child do the smurfs dream?' instead of *quale bambino sognano i puffi?* 'which child do the smurfs dream?'). This strategy is also found in the CI group but in few cases and especially with *which*-questions. For the NH group, it is found under all *wh*-conditions. Despite a difference in performance between NH and CI children, no significant difference is observed between the two groups in any of the incorrect answering strategies.

We also analysed the rate of correct responses produced by participants of the CI group in order to analyse whether participants performed following the same tendencies or a kind of variability was showed within participants.

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Table 9. Rate of correct responses for each participant of the CI group in relation to their personal and clinical data (*= missing data; HA = hearing aid; CI = cochlear implant; HE = hearing experience)

ID	Age	Age of HA	Age of CI	Length of HE	Length of use of CI	*WHO*		*WHICH*	
						subject	object	subject	object
EN	7;5	birth	0;7	7;5	6;10	50%	17%	33%	33%
CO	8;4	*	1;1	*	7;3	50%	100%	83%	67%
AT	9;0	3;6	6;10	5;6	2;2	100%	83%	100%	100%
MM	9;9	0;6	2;8	9;3	7;1	100%	100%	50%	33%
FZ	10;10	2;6	5;7	8;4	5;3	100%	100%	100%	33%
RB	9;10	*	7;8	*	2;2	100%	67%	100%	50%
SV	7;8	*	1;2	*	6;6	100%	100%	100%	83%
VZ	7;10	0;2	1;6	7;8	6;4	100%	100%	67%	67%
MS	10;0	0;5	1;2	9;7	8;10	100%	100%	100%	100%
NV	8;1	0;4	2;7	7;9	5;6	100%	83%	50%	83%
FP	13;10	*	3;1	*	10;9	50%	50%	33%	50%
ER	8;6	0;6	0;11	8;0	7;7	67%	67%	100%	33%
AM	12;8	3;0	4;6	9;8	8;2	100%	100%	100%	100%

Table 9 shows the rate of accuracy of each participant of the CI group. As the table above shows there is a high variability between subjects. For example, AT who used the CI for 2;2 years, produced a high rate of correct responses, (100% of correct responses in subject *who*- and *which*-questions and object *which*-questions; 83% in object *who*-questions). Some participants (FZ, SV, VZ, MS, AM) who have a long hearing experience with CIs showed a performance comparable to their NH age peers, namely they showed a problematic production of object *which*-questions. Some participants, even though they have a long hearing experience with CIs (EN, CO, MM, FP, ER) showed a very poor performance, which is expected in the younger participants.

In order to investigate whether clinical variables are influential factors for *wh*-questions production in children with CIs, some analyses including age at HA fitting, age at CI fitting, length of use of CIs in the model were also performed. These analyses did not reveal any effect for any of the analysed variables.

6. Discussion and conclusions

In this study, a group of 13 Italian-speaking children with CIs was assessed on the production of subject and object questions introduced by *who* or *which* followed by a noun phrase (NP). The performance of the experimental group was compared with the performance of a control group composed of thirteen NH children of comparable chronological age, in order to determine whether a significant difference in the production of *wh*-questions exists between the two groups.

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Volpato and D'Ortenzio (2017) carried out a pilot study in which they compared the productions of *wh*-questions of a group of 8 children fitted with CIs to a group of 8 normal hearing age peers. They showed that the two groups performed following the same tendency, namely subject *wh*-questions were easier than object *wh*-questions and *who* questions were less problematic than *which* + NP questions. Also in the present study CI and NH children showed the same trend pointed out by Volpato and D'Ortenzio's (2017) pilot study. Indeed, object *wh*-questions were more difficult to produce than subject *wh*-questions, and *which* + NP questions were harder to produce than *who* questions. Differently from Volpato and D'Ortenzio (2017), in this study, repeated measure logistic regression analyses in a mixed model were carried out and showed that no significant difference was found between the CI and NH groups. In this respect, the results of the present study are different from those of previous cross-linguistic studies carried out on individuals with hearing impairment (Friedmann and Szterman 2011, Friedmann and Haddad-Hanna 2014, Ruigendijk and Friedmann 2017, Penke and Wimmer 2018), in which a significant difference was found between experimental and control samples. Differently from the previous studies, in which the experimental samples were heterogeneous as far as the type of device used (HAs or CIs), the present study exclusively includes children with CIs. Therefore, it seems that the use of CIs increases accuracy in the production of *wh*-questions and reduces the gap between children with hearing impairment and children with normal hearing.

Focusing on the types of constructions included in the elicitation test, two typical asymmetries were identified: (i) between subject and object *wh*-questions, the former being easier than the latter, and (ii) between *who* and *which* + NP questions, being the former less demanding than the latter. Our data confirm previous studies on the comprehension and the production of *wh*-questions in populations with typical and atypical language development (TD children and adults: De Vincenzi 1991, 1999, Friedmann et al. 2009, Guasti et al. 2012, Belletti and Guasti 2015; children with developmental dyslexia: Guasti et al. 2015, Del Puppo et al. 2016; patients with agrammatic aphasia: Garraffa and Grillo 2008; children with hearing loss: Quigley et al. 1974, Friedmann and Szterman 2011, Friedmann and Haddad-Hanna 2014, Ruigendijk and Friedmann 2017, Volpato and D'Ortenzio 2017, Penke and Wimmer 2018).

In order to explain the asymmetries found in the production, comprehension, and processing of *wh*-questions, we considered two hypotheses put forward in the literature: The Minimal Chain Principle (MCP, De Vincenzi 1991), and the Agree Interference Approach (AIA, Guasti et al. 2012).

Following De Vincenzi's MCP (1991, 1999), children's misinterpretation of object *wh*-questions is due to economy reasons. Taking into consideration the dependency between the *wh*-element and the position from which it has been moved, either the subject or the object position, the parser avoids keeping in memory the moved element for a long time by promptly interpreting it. Therefore, subject *wh*-questions are easier because the dependency between the *wh*-element and its copy in subject position is shorter than the dependency in object *wh*-questions, where the *wh*-element moves from the object position. Long dependencies, like those found in object questions, increase the computational load necessary to produce these sentences. Since the first element met by the parser, namely the *wh*-element with the object function, does not agree with the verb, the initial analysis of the parser is not confirmed by new incoming material and a new

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analysis must be done in order to reassign new grammatical function, thematic role, and case to the object chain. This hypothesis is supported by one of the errors made by the children, namely the production of a subject *wh*-question (*Chi lava i cani?* 'who washes the dogs?') instead of an object *wh*-question (*Chi lavano i cani?* 'who wash-3PL the dogs-SUBJ?'). In a nutshell, De Vincenzi et al. (1999) assume that Italian-speaking children misinterpret object *wh*-questions, because they posit a gap in the subject position and, obeying the MCP, fail to revise the initial incorrect analysis.

However, although the MCP explains the subject/object asymmetry in the comprehension and production of *wh*-questions, it does not explain the reason why, especially with object *wh*-questions, children resort to several strategies in order to facilitate the production of an object *wh*-question. Guasti et al. (2012) faced this question proposing the AIA, which built on the proposal by Guasti and Rizzi (2002), and Franck et al. (2006). The AIA hypothesis was grounded on the subject-verb agreement relation, since agreement is crucial to decide whether a subject or an object question is meant in Italian. Agreement usually occurs in two steps: AGREE and Spec-Head agreement. Through AGREE the subject in the specifier of the vP checks its person and number features against the inflectional node AgrS, under c-command and in a local configuration. Spec-Head agreement is an optional operation that takes place only when the subject moves from specvP to Spec/AgrS, and through which it is possible to verify whether the subject and the verb share the same features. The movement of the object to the left-periphery involves a movement to an intermediate projection (AgrOP) before landing in the CP. Considering AGREE, when AgrS checks its features in its c-commanding domain, it first finds the object or its copy in Spec/AgrOP, which can be mistaken for AgrS and transfer its features to it. Therefore, the object intervenes in the AGREE relation between the thematic subject in Spec/vP and AgrS and induces attraction errors, since it is possible for the object to be valued as AgrS. In VS sentences agreement is checked only once, allowing interpreting errors. For this reason, children resorted to other strategies when an object *wh*-question was elicited because the object functions as intervener in the AGREE relation between the post-verbal subject in Spec/vP and AgrS (Guasti et al. 2012). In production, several strategies of asking a question are available to children (Belletti and Guasti 2015, Del Puppo et al. 2016).

One of the strategies in support of this hypothesis is the recourse to passive by older children (in both the experimental and the control groups). Passive sentences allow to bypass the interference effect in the AGREE relation, since in passive structures the logical object becomes the subject and the logical subject is demoted to an adjunct status. This means that AgrS checks the agreement relation with the internal argument, allowing the production of a passive subject *wh*-question instead of an object *wh*-question.

According to Guasti et al. (2012, 2015) and Belletti and Guasti (2015), the asymmetry between *who*- and *which*-questions is due to several processes involved in the derivation of *which* + NP questions. On the one hand, the structural complexity of the *which* + NP element, since the movement of the *which*-phrase involves pied piping of the nominal element (Belletti and Guasti 2015). This hypothesis is supported by the several errors made by both CI and TD children, for example, when children produce questions in which the *wh*-operator and the nominal element are separated (*Il cuoco, quale sta salutando dei calciatori?* 'The cook, which is greeting of the football players?'), or simplify the *which* + NP into *who* (*Chi lava le scimmie?* 'Who washes the monkeys?'

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instead of *Quale gatto lava le scimmie?* 'Which cat washes the monkeys?'). The avoidance of the *which* + NP question when pragmatically required is a strategy that makes it possible for the children to reduce the complexity of this kind of sentence. On the other hand, agreement relations also condition the right interpretation of *which* + NP questions, since both the subject and the object display agreement features and must agree. Moreover, in subject *wh*-questions, it is the *which*-phrase that agrees with the verb. This latter hypothesis is confirmed when children leave the *which* + NP in its original position, namely they produced an *in-situ* question (*La fatina tira quali bambini?* 'The fairy pulls which children?'). However, agreement may not be a problem per se, since Italian-speaking children can already master agreement at 2-3 years, but it becomes a problem when it occurs with pied piping, which is much demanding for children's computational system (Belletti and Guasti 2015).

As pointed out above, comparing the performances of the two groups, the data analysis showed lower percentages of correct sentences in the CI group as opposed to the NH one for all sentence conditions, except for subject *who*-questions.

In the present study, it is interesting to observe that the children fitted with CIs adopted a large number of strategies when both subject and object questions were targeted. Carrying out a more qualitative analysis, we compared the rate of correctness for each participant of the CI group, and we found a high variability in the responses given. The most frequent (incorrect) strategy was the production of ungrammatical sentences, which were uttered by the youngest and by two of the older participants with CIs. In addition, most children with CIs replaced the *wh*-element with one which was not appropriate for the context (for example, they used *chi* 'who' instead of *which* + NP). This strategy was observed in many children, regardless of their age. In some cases, children produced *wh*-questions with reversed thematic roles. However, some other children with CIs who did not produce the target sentence used some strategies that were nonetheless pragmatically correct, such as topicalised sentences, cleft *wh*-questions, and sentences in which the *which* + NP element was substituted with *che* + NP '*what* + NP'. This last strategy is largely used in some dialectal varieties of Italian and was considered as correct because both *wh*-elements involve pied piping. However, *what* + NP pragmatically differs from the target *which* + NP since it is used to refer to a non-rigid domain, which does not presume the choice between two distinct options (Fava 2001).

Concluding, confirming what has been shown by previous studies in the comprehension and production of *wh*-questions in hearing impaired children (Friedmann and Szterman 2006, Szterman and Friedmann 2014, Ruigengijk and Friedmann 2017, Volpato and D'Ortenzio 2017, Penke and Wimmer 2018), the CI children who produced correct and appropriate sentences displayed a good competence of Italian and used response strategies also found in NH children; other CI children, who produce ungrammatical sentences, showed an atypical behaviour that is evidence of the linguistic deficit associated to hearing impairment. Investigating the role of clinical variables in the performarce of children with CIs, it was found that HA fitting, age at CI fitting, length of use of CIs are not significant predictors of performance.[6]

[6] Some studies claim that the performance could be influenced by several external factors, such as number of hours per day that children use the device, the higher level of maternal instruction, the absence of other disabilities (Blamey et al. 2012, Govaerts 2016). In our study, we did not control for the role of these variables. This could be an interesting aspect to be analysed in future research.

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