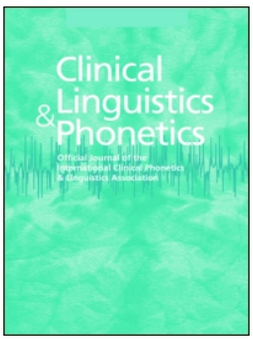

Clinical Linguistics & Phonetics

ISSN: 0269-9206 (Print) 1464-5076 (Online) Journal homepage: https://www.tandfonline.com/loi/iclp20

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To cite this article: Silvia D'Ortenzio & Francesca Volpato (2019): How do Italian-speaking children handle *wh*-questions? A comparison between children with hearing loss and children with normal hearing, Clinical Linguistics & Phonetics, DOI: 10.1080/02699206.2019.1677779

To link to this article: https://doi.org/10.1080/02699206.2019.1677779

Published online: 29 Oct 2019.

CLINICAL LINGUISTICS & PHONETICS
https://doi.org/10.1080/02699206.2019.1677779

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How do Italian-speaking children handle *wh*-questions? A comparison between children with hearing loss and children with normal hearing

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ABSTRACT

In this paper, we analyse how Italian-speaking children with cochlear implants produce subject and object questions introduced by *who* and *which*+NP. The aim of the study is to analyse whether a correlation exists between the accuracy of the responses of an elicitation task of *wh*-questions and clinical variables (i.e. age of hearing aid fitting; age of cochlear implantation; duration of hearing experience) in a group of children with cochlear implants, in order to provide new evidences in support of the efficacy of early intervention in Italian-speaking children with hearing loss. The experimental group was composed of 10 children fitted with a cochlear implant, who were diagnosed and promptly fitted with hearing aids within the first year of life. All these participants received a cochlear implant when hearing aids did not provide enough auditory input anymore. Indeed, while the hearing aids only amplify sounds, cochlear implants directly stimulate the auditory nerve providing better auditory perception. Results were compared with those of two control groups. The first group was composed of 10 children with normal hearing and comparable chronological age, while the second group was composed of 10 children with normal hearing matched on comparable hearing experience. Children were assessed with a test for the elicitation of subject and object *who* and *which*+NP questions. Results show that the two control groups performed better than the experimental group. Moreover, some correlations were found between the accuracy of the production of complex structures and the age of fitting of the hearing aids and the hearing experience.

ARTICLE HISTORY
Received 23 February 2019
Accepted 3 October 2019

KEYWORDS
Syntax; *wh*- questions; hearing loss; hearing aids; cochlear implants

Introduction

Children start to master *wh*-questions early in life. For instance, English-speaking children produce subject *who*-questions correctly by age 2 (O'Grady, 2005; Yoshinaga, 1996). Early studies on language acquisition in Italian pointed out that children master *wh*-questions introduced by *cosa* 'what' or subject *chi* 'who' already at the age of 2 (Guasti, 1996). A similar pattern has also been found in other languages such as Hebrew (Friedmann, Belletti, & Rizzi, 2009) Greek (Stavrakaki, 2006) German (Clahsen, Kursawe, & Penke, 1996; Siegmüller, Herzog, & Herrmann, 2005).

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For Italian, several studies (Belletti & Guasti, 2015; Del Puppo, 2016; De Vincenzi, 1991; De Vincenzi, Arduino, Ciccarelli, & Job, 1999; Guasti, 1996; Guasti, Branchini, & Arosio, 2012; Guasti, Branchini, Vernice, Barbieri, & Arosio, 2015) pointed out that subject *wh*-questions are acquired earlier and are easier than object *wh*-questions. De Vincenzi et al. (1999) carried out a study on the comprehension of *who* and *which*+NP subject and object questions in a group of children ranging in age from 3;0 to 11;0. The results showed that children aged 4 are already capable of comprehending subject *wh*-questions correctly, while the comprehension of *wh*-object questions appeared to be delayed. Indeed, object *wh*-questions are found to be comprehended at ceiling only by children aged between 10:0 and 11;0. Moreover, until the age of 7;0 children show an asymmetry between the comprehension of *who* and *which*+NP questions, the former being easier than the latter. As for the production, Guasti et al. (2012) assessed a group of Italian-speaking typically developing children ranging in age from 4;0 to 5;0 on the production of subject and object *who* and *which*+NP questions. Results showed that children of this age perform better in the production of subject *who*-questions than object *who*-questions, while lack of significance was found between the production of subject and object *which*+NP-questions, namely in these structures children showed a low performance. A similar asymmetry in the acquisition of subject and object *wh*-questions has also been found in children with hearing loss fitted with hearing aids (HA) and/or cochlear implants (CI) (Friedmann & Haddad-Hanna, 2014; Friedmann & Szterman, 2006, 2011; Penke & Wimmer, 2018; Szterman & Friedmann, 2015; Volpato & D'Ortenzio, 2017, 2018). As pointed out by these studies, children with hearing loss and fitted with a prosthetic device show a delay in the acquisition of *wh*-questions because of the complex syntactic structure of these sentences. For instance, Italian *wh*-questions are characterised by the structure *Wh*-V(erb)-N(oun), namely the *wh*-element is followed by the verb and a noun being either the object or the subject of the sentence (Belletti & Guasti, 2015; Cardinaletti, 2003; Greco, 2013). In subject *wh*-questions, the *wh*-element is the subject of the sentence, while the post-verbal noun is the object, thus the question presents an unmarked, canonical order of the constituents, namely the subject precedes the verb and the direct object (SVO). In object *wh*-questions the canonical order of constituents is violated because the *wh*-element is the object of the sentence and the post-verbal noun is the subject of the sentence, resulting in the marked OVS structure. The subject is in a postverbal position to satisfy the adjacency requirement between the *wh*-element and the verb, namely, a *wh*-phrase must be in a Spec-head configuration with a head marked with the same feature (Rizzi's Wh criterion, Rizzi, 1996). Indeed, even though Italian is an SVO language, the subject cannot follow the *wh*-element (Cardinaletti, 2003; Greco, 2013). The following examples show the different structure of Italian subject *who*-questions (1); object *who*-questions (2); subject *which*+NP-questions (3); object *which*+NP-questions (4).

(1) Chi pettina i gatti?
'Who combs the cats?'.

(2) Chi pettinano i gatti?
who comb-3PL the cats
'Whom do the cats comb?'.

(3) Quale giraffa pettina i gatti?
which-SG giraffe combs the cats
'Which giraffe combs the cats?'.

(4) Quali gatti pettina la giraffa?
which-PL cats combs the giraffe
'Which giraffe do the cats comb?'.

Assuming Chomsky (1977, 1981; see also Rizzi 1997), *wh*-questions are characterised by a dependency between the *wh*-operator in sentence initial position and a gap in the *wh*-operator base position, where it is interpreted. Start the sentence with: In subject *wh*-questions (5–6), the subject leaves a trace in preverbal position resulting in a short dependency; while in object questions (7–8) the object leaves a trace in postverbal position resulting in a long dependency.

(5) [$_{CP}$ Chi <chi> pettina i gatti?]
[$_{CP}$ Who <who> combs the cats?]
'Who combs the cats?'.

(6) [$_{CP}$ Quale giraffa <quale giraffa> pettina i gatti?]
[$_{CP}$ which-SG giraffe <which giraffe> combs the cats?]
'Which giraffe combs the cats?'.

(7) [$_{CP}$ Chi pettinano i gatti <chi>?]
[$_{CP}$ who comb-3PL the cats <who>?]
'Whom do the cats comb?'.

(8) [$_{CP}$ Quali gatti pettina la giraffa <quali gatti>?]
[$_{CP}$ which-PL cats combs the giraffe <which cats>?]
'Which cats does the giraffe comb?'.

A further asymmetry exists between *who*-questions and *which*+NP-questions, thus the former structure being easier to process than the latter (Guasti et al., 2012, 2015; Volpato & D'Ortenzio, 2017, 2018). In this case, the difficulty in the processing of the *wh*-question is caused by the number of elements involved in the movement from the base position to the new position at the beginning of the sentence. Indeed, while in *who*-questions only the *wh*-operator moves, in *which*+NP-questions there are two elements moving to the beginning of the sentence. According to the Derivational Complexity Hypothesis (Jakubowicz, 2004, 2005, 2011), children acquire less complex structures (*who*-questions) before structures involving more complex derivational movement (*which*+NP-questions).

Previous studies on the processing of *wh*-questions in children with hearing loss

Sensorineural hearing loss is caused by a dysfunction of the cochlea or by a problem of the auditory nerve (Govaerts et al., 2002; Martini, Bovo, Trevisi, Forli, & Berrettini, 2013). The damage in one of these areas prevents the transformation of the acoustic stimuli into neurological signals causing a misprocessing of the auditory information by the brain (Aimar, Schindler, & Vernero, 2009; Kral & O'donoghue, 2010).

It has been found that infants who are diagnosed early, even at birth, and receive hearing aids (HA) within the ninth month of life can reach good performances across a range of communication skills (Ambrose et al., 2014; Caselli, Rinaldi, Varuzza, Giuliani, & Burdo, 2012; Watkin et al., 2007; Yoshinaga-Itano, 2003). However, in many cases HA does not provide enough linguistic input necessary for the acquisition of an oral language. In these cases, a cochlear implant (CI) may be necessary. A CI is an electronic device that is partially implanted and provides a sense of sound to individuals with severe-to-profound hearing loss. Children with CI show high levels of accuracy in some linguistic aspects of language, for example in the acquisition of vocabulary or in speech perception (Caselli et al., 2012; Chilosi et al., 2013; Rinaldi & Caselli, 2009). However, some of them still show syntactic difficulties especially related to movement-derived structures, such as relative clauses (Friedmann & Szterman, 2006; Volpato, 2010, 2012; Volpato & Adani, 2009; Volpato & Vernice, 2014), *wh*-questions (Friedmann & Szterman, 2011; Penke & Wimmer, 2018; Ruigendijk & Friedmann, 2017; Szterman & Friedmann, 2015; Volpato & D'Ortenzio, 2017, 2018), clitic pronouns (Chesi, 2006; Guasti et al., 2014). These difficulties may be caused by technical limitations of hearing devices (HA, CI) that often result in only partial compensation of hearing loss (Bentler, Walker, McCreery, Arenas, & Roush, 2014).

For Hebrew, Friedmann and Szterman (2006) showed that children with hearing loss and fitted with either HA or CI show a deficit in the processing of movement-derived sentences because of asyntactic movement with noncanonical order of constituent (structures involving movement of the object) resulting in structures with noncanonical order of constituents, for example object relative clauses. Object *wh*-questions may be an obstacle for children with hearing loss since also these structures are derived by syntactic movement of the object. Friedmann & Szterman found that performance correlated with early intervention. Indeed, children whose hearing loss was identified very early (8 months) and promptly received HA and speech therapy showed better performance in the sentence comprehension tasks.

Penke and Wimmer (2018) tested a group of 21 German-speaking children with hearing loss fitted with HA aged between 3 and 4 years on the comprehension of subject and object *who*-questions with a picture pointing task. They compared the performance of the experimental group with a control group of 19 normal hearing age peers. Overall, the percentage of correct answers provided by children with hearing loss was 78%, which was significantly lower than the percentage of correct answers found in the control group (93%). However, while normal hearing children perform similarly in subject and object questions, children with hearing loss show very low performance in the comprehension of object questions. Differently from Friedmann and Szterman (2006), Penke and Wimmer did not find any correlation between the age of HA fitting and rate of accuracy.

Volpato and D'Ortenzio (2018) carried out a study on 13 Italian-speaking children with CI on the production of subject and object *who* and *which*+NP questions. The participants, ranging in age from 7;5 to 13;10, were diagnosed and fitted with HAs between birth and 3;6. Because the HA did not provide enough linguistic input, all participants received a CI between 0;7 and 7;8 years. Therefore, the experimental group was highly heterogeneous. The participants' performance was compared with those of a control group of 13 Italian-speaking children with normal hearing with comparable chronological age. Results showed that overall, children with CI performed worse than their normal hearing age

peers (rate of accuracy: CI: 76%; NH: 85%). As in Penke and Wimmer (2018), also in Volpato and D'Ortenzio, both the experimental and the control groups presented the typical subject/object asymmetry. In children with CI and children with normal hearing a further asymmetry was observed between *who*- and *which*+NP questions, namely *who*-questions were easier to produce than *which*+NP-questions. This asymmetry was previously discussed by Guasti et al. (2012), who analysed the production of subject and object *who* and *which*+NP-questions in a group of typically developing children aged between 4 and 5 years. To explain this asymmetry, Guasti and her collaborators proposed the Agree Interference Approach (AIA), which explains that lower percentages of accuracy are ascribable to a problem in the processing of the subject-verb agreement relation. The same proposal was put forward by Guasti et al. (2015) for a group of children with developmental language disorder, who were less accurate in the production of object *wh*-questions than in the use of subject questions. Since also in Volpato and D'Ortenzio (2018) the production of object *wh*-questions was found more demanding than the production of subject *wh*-questions, the authors hypothesized that also children with hearing loss may experience the same difficulties in the processing of the subject-verb agreement relations. As in Penke and Wimmer (2018) any significant correlation was found between accuracy and age of HAs fitting. This result was likely due to the heterogeneity of the experimental group.

For this reason, in this study, we created a more homogeneous experimental group, namely we included only children who received their HA within the first year of life in order to analyse whether a correlation exists between the age of HA, the following age of CI, the length of exposure to the oral language, and the rate of accuracy of the collected responses. These clinical variables were chosen following the study by Friedmann and Szterman (2006) where the age of intervention, the type of hearing aid, the duration of use of a CI, and the degree of hearing loss were considered for correlation analyses with the performance of the children with hearing loss. In this study, we did not consider the variable 'degree of hearing loss' since all the participants with hearing loss suffer from severe to profound hearing loss (>70 dB). Moreover, the presence of a more homogeneous group would make it possible to obtain more reliable results as for the investigation of syntactic competence and the relationship between HA or CI fitting and the production of complex syntactic structures.

The importance of early intervention was pointed out more than 30 years ago (Oller & Eilers, 1988) and then confirmed by following studies (Johnson & Goswami, 2010; Moeller, 2000; Schauwers, Gillis, & Govaerts, 2005; Yoshinaga-Itano, Baca, & Sedey, 2010), which pointed out that children receiving early intervention show better performance in phonology and receptive vocabulary than children who received later intervention. Moreover, recent studies have pointed out that language acquisition in children fitted with either HA and/or CI may be influenced by further external factors such as a constant usage of the device, the maternal instruction, and the absence of other disabilities (Fitzpatrick et al., 2012; Holt & Svirsky, 2008; Marname & Ching, 2015; Niparko et al., 2010; Spencer, Marschark, & Spencer, 2011; Tomblin et al., 2015). In this study, we investigate the relationship between the production of *wh*-questions and some clinical variables, namely age of HA fitting, age of cochlear implantation, and length of exposure to the oral language, in order to check whether these variables are significant predictors in the production of some complex syntactic structures in Italian. We aimed to replicate the

analyses of Friedmann and Szterman (2006), which showed that an early intervention correlates with the performance of the children with hearing loss.

Methodology

Participants

Children with hearing loss

We analysed the performance of 10 children with prelingual sensorineural hearing loss fitted with CI (CI group). Children ranging in age from 7;10 to 12;10 (mean age: 10;0). They were diagnosed and fitted with HA within the first year of life, thus their hearing experience varied between 7;8 and 12;0 years (mean age: 9;5). They received CIs between 1;0 and 9;8 years (mean age 4;4). Individual hearing thresholds were diagnosed via clinical audiometry based on pure tone averages at 500, 1000, 2000 and 4000 Hz (PTA_2). According to the classification of the WHO (World Health Organisation, 2018), all participants suffer from severe to profound hearing loss (>70 dB). Moreover, a speech perception test was carried out by speech therapists to assess whether the participants had a proper perception of normal speech. Children are all born in hearing families and had been trained orally. None of them know or use sign language. Most of them came from Northern Italy (nine participants), while one participant came from Central Italy. They were selected and tested at the Ear Nose Throat Clinic (ENT Clinic) of the Department of Neurosciences of the University of Padua. Table 1 shows personal (age) and clinical data (type of hearing loss; age of HA fitting; age of CI; length of hearing experience) of the participants of the CI group.

Control groups

The results of the CI group were compared with the results of two control groups. One control group was composed of 10 children matched on comparable chronological age (CA group, age range: 7;10–12;9; mean age: 10;1). The other control group included 10 children with comparable length of exposure to the oral language (HE group, age range: 7;10–12;1; mean age: 9;5). The children from both groups came from several regions of Italy. Table 2 shows personal data of the participants of the control groups. We performed ANOVA analyses on chronological age of the CI group and CA group, and on the length

Table 1. Personal and clinical data of the participants of the CI group (HL = hearing loss; HA = hearing aid; CI = cochlear implant; HE = hearing experience).

ID	Age	HL type	Age of HA	Age of CI	Length of HE
CI1	10;2	Sensorineural	1;0	9;8	9;2
CI2	10;0	Sensorineural	0;5	1;2	9;7
CI3	7;10	Sensorineural	0;2	1;6	7;8
CI4	8;6	Sensorineural	0;7	4;7	7;9
CI5	11;6	Sensorineural	0;6	6;7	11;0
CI6	9;9	Sensorineural	0;5	2;9	9;4
CI7	12;10	Sensorineural	0;10	6;7	12;0
CI8	10;5	Sensorineural	0;6	2;3	9;11
CI9	10;5	Sensorineural	0;6	7;3	9;11
CI10	8;6	Sensorineural	0;6	1;0	8;0

Table 2. Personal data of the two control groups (CA = chronological age; HE = hearing experience).

Group	ID	Age
CA	**CA1**	10;3
CA	**CA2**	10;4
CA	**CA3**	7;10
CA	**CA4**	8;8
CA	**CA5**	10;11
CA	**CA6**	9;7
CA	**CA7**	12;1
CA	**CA8**	8;3
CA	**CA9**	12;9
CA	**CA10**	9;10
HE	**HE1**	8;8
HE	**HE2**	9;6
HE	**HE3**	7;10
HE	**HE4**	7;10
HE	**HE5**	10;11
HE	**HE6**	9;5
HE	**HE7**	12;1
HE	**HE8**	9;7
HE	**HE9**	10;3
HE	**HE10**	8;0

of hearing experience of the CI group and HE group, and we did not find any significant difference (CI vs. CA: p = .756; CI vs. HE: p = .733).

Materials

The participants were administered an elicitation task of *wh*-questions (Guasti et al., 2012, 2015). The task includes 24 items, investigating the use of subject and object *who* and *which*+NP questions. The four conditions are shown in Table 3.

In this task, only transitive reversible verbs were used, thus, to prevent the participants from deriving the meaning of the sentence by relying on semantic or pragmatic cues. Figure 1 shows an example of an item used for the elicitation of a subject *who*-question.

When Figure 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?".

When eliciting a *which*+NP-question, the experimenter presented two pictures successively. The characters were presented in the first picture, then the picture eliciting the

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?* whom do the elephants dirty?
	Which	*quale cane leccano i gatti?* which dog do the cats lick?

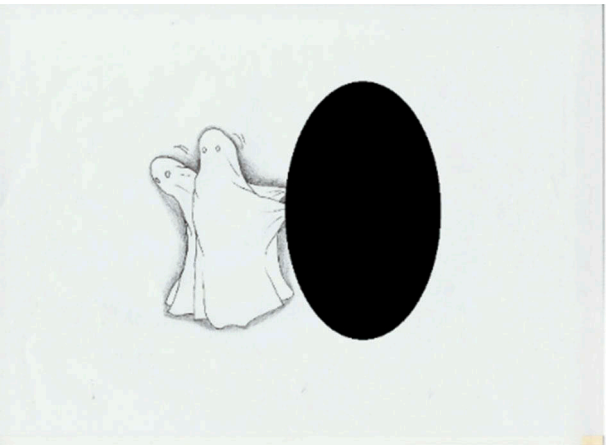

Figure 1. Picture eliciting a subject who-question.

target question was presented. Figure 2 provides an example of elicitation of a *which*+NP-question.

When a *which*+NP question was elicited, 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, children with CI could also rely on lip reading. Then, children were invited 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 screen, and the stimuli were displayed through a PowerPoint presentation. The questions produced by the participants were audiotaped and transcribed by one of the experimenters.

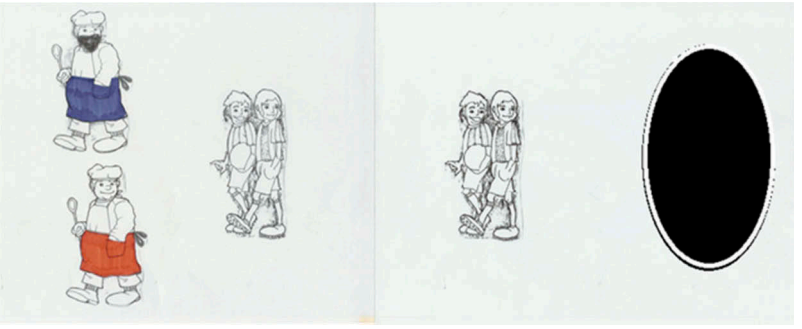

Figure 2. Picture eliciting a subject which+NP-question.

Response coding

Since Italian offers a wide range of possibilities when eliciting a *wh*-question, first we will present the strategies considered as correct and appropriate for the context and then the strategies that are incorrect. For response coding we refer to Guasti et al. (2012, 2015) since we used the same task, in order to be able to perform a more direct comparison.

Both subject and object *who-* and *which*+NP questions were considered correct when they showed the word order *Wh* V N (9) or when a cleft structure was produced (10):

(9) a. Chi acchiappa i fantasmi? — Subject *who*-question‘
Who catches the ghosts?’.

b. Chi colpiscono i bambini? — Object *who*-question
who hit-3PL the children
‘Whom do the children hit?’.

c. Quale gatto lava le scimmie? — Subject *which*+NP-question
which-SG cat washes the apes
‘Which cat washes the apes?’.

d. Quale gatto lavano le scimmie? — Object *which*+NP-question
which-SG cat wash-3PL the apes
‘Which cat do the apes wash?’.

(10) a. Chi è che acchiappa i fantasmi? — Subject *who*-question
who is that catches the ghosts
‘Who catches the ghosts?’.

b. Quale gatto è che lava le scimmie? — Subject *which*+NP-questions
which-SG cat is that washes the apes
‘Which cat washes the apes?’.

As for object questions, responses were considered grammatically and pragmatically correct when the subject DP was topicalized (11), when the subject was not expressed (12), or when a passive *wh-* question was produced (13):

(11) I bambini, chi colpiscono?
the children, who hit-3PL
‘Whom do the children hit?’.

(12) Chi colpiscono?
who (they) hit-3SG
‘Whom do the children hit?’.

(13) Chi è colpito dai bambini?
‘Who is hit by the children?’.

Some children produced questions in which the *wh*-element *which* was replaced by *che* "what" (*Che*+NP). This strategy is common in Italian in the oral/colloquial language. The response was considered correct, since also in these structures the *wh*-element *che* moves together with a NP as in *which*+NP-questions.

(14) 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?'.

We analysed as incorrect some questions that were grammatically correct, but pragmatically infelicitous, as for instance sentences targeting a *which*+NP question, but introduced by the element *who* (15) or questions with theta-role inversion (16):

(15) 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?'.

(16) 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 (17) and *wh*-questions containing resumptive clitic pronouns (18):

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

(18) 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 (19), questions containing only the (complex) *wh*- element (20), incomplete sentences (21), and sentences that consists in the repetition of the last part of the stimulus read by the experimenter (22).

(20) Quali cavalli insegue i leoni?
'Which horses follows the lions?'

(21) Quale cuoco?
'Which cook?'

(22) Un bambino fa qualcosa …
'A child makes something … '

(23) Qualcuno acchiappa i fantasmi, chi è?
'Someone catches the ghosts, who is?'

Results

Table 4 shows the number and raw proportion of correct responses provided by each group in each condition.

As shown in Table 4, all groups performed at ceiling in the production of subject *who*-questions. The CI group performed worse than the two control groups in the production of object *who*-questions, and in both subject and object *which*+NP-questions. Finally, also in the two control groups the production of object *which*+NP questions was found problematic.

As said in the section 'Response coding' above, we considered as correct several structures in addition to the typical structure of *wh*-questions in Italian (*Wh* V N). Therefore, we also investigated the different strategies adopted by each group when subject and object questions were produced. Table 5 presents the proportion of raw scores of correct strategies used by each group to produce the elicited structures.

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			CA			HE		
		No.	Mean	SD	No.	Mean	SD	No.	Mean	SD
WHO	SQ	58/60	0.97	0.18	58/60	0.97	0.18	58/60	0.97	0.18
	OQ	50/60	0.83	0.37	55/60	0.92	0.28	54/60	0.90	0.3
WHICH	SQ	45/60	0.75	0.43	56/60	0.93	0.25	55/60	0.92	0.28
	OQ	41/60	0.68	0.47	53/60	0.88	0.32	51/60	0.85	0.36
TOTAL		**194/240**	**0.81**	**0.39**	**222/240**	**0.93**	**0.26**	**218/240**	**0.91**	**0.29**

Table 5. Proportion of raw scores in the use of the different correct strategies by group and by question type (SQ = subject question; OQ = object question).

	CI				CA				HE			
	WHO		WHICH		WHO		WHICH		WHO		WHICH	
	Subj.	Obj.	Subj.	Obj.	Subj.	Obj.	Subj.	Obj.	Subj.	Obj.	Subj.	Obj.
Wh V NP	0.68	0.37	0.60	0.32	0.80	0.62	0.87	0.53	0.78	0.68	0.87	0.45
Topicalized	–	0.20	–	0.05	–	0.13	–	0.07	–	0.05	–	0.03
Cleft	0.18	–	0.02	0.02	0.17	0.03	–	–	0.17	0.03	–	–
No argument	–	0.12	–	0.10	–	0.03	–	0.02	–	0.03	–	0.10
Passives	–	0.10	–	0.15	–	0.08	–	0.22	–	0.08	–	0.22
CHE+NP	–	0.03	0.02	0.03	–	0.02	0.07	0.05	–	0.02	0.05	0.05
Other right	0.10	0.02	0.12	0.02	–	–	–	–	0.02	–	–	–

The most used strategy in all groups was the production of a *wh*-question with the final NP (*Wh* V NP). Common to all groups was the high occurrence of this strategy in the production of subject questions, while in the production of object *wh*-questions, since participants from the experimental and control groups resorted to several strategies when an object *wh*-question was elicited. *Wh*-questions with a topicalised structure were produced by CI and CA groups when an object *who*-question was elicited. This structure is rarely found in the HE group. Cleft *wh*-questions are largely produced by all groups when a subject *who*-question was elicited. The CI group produced a higher rate of *wh*-questions lacking the argument than the other control groups. Passives are found more in the CA group than in the CI and in the HE groups. The substitution of *quale* 'which' for *che* 'that' is found with similar proportions in all the groups involved in this study. Finally, children with CI also resorted to other strategies when a *wh*-question was elicited.

The use of incorrect strategies was also analysed. Table 6 shows the proportion of raw scores of incorrect strategies used by the experimental and the control groups when a *wh*-question was elicited.

Even if the rate is low, the substitution of the *wh*-operator is a strategy commonly used by the two control groups. The production of ungrammatical or incomplete *wh*-questions is largely found in the CI group. The production of *wh*-questions with theta-role inversion (*Quale cuoco saluta i bambini?* 'Which cook greets the children?' instead of *Quale cuoco salutano i bambini?* 'Which cook do the children greet?') was more frequent in the CI group than in the control groups. The production of in situ *wh*-questions was rarely used when an object *which*+NP-question was elicited. Only children with CIs produced *wh*-question with resumptive clitic pronouns. Finally, resorting to other strategies in order to avoid the production of target *wh*-questions was found more in the CI group than in the two control groups.

In order to analyse whether the results were significant, we carried out some statistical analyses using the statistical software R (R Development Core Team, 2018, R Version 3.6.1). Following the reviewers' comments to our previous analyses, we tried to carry out an ANOVA analysis, in order to use a single multinomial analysis to compare the mean of the correct responses (TARGET) to the type of the experimental items (subject and object *who*-questions, subject and object *which*+NP-questions) considering the variable GROUP as interaction. Since data did not converge, we carried out repeated measure logistic regression analyses in a mixed model, in which a model including the predictor is

Table 6. Proportion of raw scores in the use of the different incorrect strategies by group and by question type.

	CI				CA				HE			
	WHO		WHICH		WHO		WHICH		WHO		WHICH	
	Subj.	Obj.	Subj.	Obj.	Subj.	Obj.	Subj.	Obj.	Subj.	Obj.	Subj.	Obj.
Other wh-	–	–	0.03	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.05	0.03
ungrammatical/ incomplete	0.02	0.08	0.17	0.17	0.02	0.03	0.03	0.03	0.03	0.03	0.03	–
Theta inversion	–	0.05	0.03	0.02	–	0.03	–	0.02	–	–	–	–
In situ	–	–	–	0.02	–	–	–	0.02	–	–	–	0.08
Clitic pronoun	–	–	0.02	0.02	–	–	–	–	–	–	–	–
Other strategies	0.02	0.03	–	0.08	–	–	–	0.02	–	–	–	0.03

contrasted against a model without it using a χ^2-test (Jaeger, 2008)[1] We chose this type of statistical analysis because of the categorical (dichotomic) nature of the collected data.

The first analysis we carried out considered as independent fixed factors GROUP (CI vs. CA, CI vs. HE), the dependent variable was response accuracy[2], and SUBJECT and ITEM were random factors. Estimated coefficients, standard errors, Z-values, and associated *p*-values for GROUP are shown in Table 7.

As reported in Table 7, the performance of the CI group was significantly different from the performance of both control groups. Since *wh*-questions in Italian can be produced resorting to several strategies, we performed a second analysis considering only the structures with the constituent order *Wh* V Nas the dependent variable. A significant difference was found between the performance of the CI group and the performance of each of the two control groups. Table 8 shows the main results of this analysis.

We then performed the same analysis considering as the dependent variable the other correct structures used by the children when they did not produce a *wh*-question with the typical order *Wh* V N. In order to avoid the instability of the model, we grouped all the strategies adopted by the participants under the same variable OTHER STRATEGIES. In this case we did not find a difference between the experimental and the control groups. Results are shown in Table 9.

The second analysis considered as independent fixed factor SENTENCE TYPE (subject questions vs. object questions), the dependent variable was response accuracy, and SUBJECT and ITEM were considered as random factors. Results showed that subject questions are significantly more accurate than object *wh*-questions. Table 10 shows the results of the statistical analysis.

The third analysis considered as independent fixed factor WH-ELEMENT (*who* vs. *which*+NP), the dependent variable was response accuracy, and SUBJECT and ITEM were considered as random factors. Results showed that *who* questions are significantly more accurate than *which*+NP questions. Table 11 shows the results of the statistical analysis.

Table 7. Estimated coefficients, standard errors, Z-values, and associated p-values for the group factors.

Groups	Estimate	SE	Z	p
CI vs. CA	1.2297	0.5497	2.237	.003
CI vs. HE	1.1181	0.5444	2.054	.04

[1]Assuming Dixon (2008) and Jaeger (2008), analysing categorical outcomes with ANOVA can lead to incorrect interpretations of results. Conversely, resorting to mixed logit models is more trustworthy, thus this type of analysis yields two advantages. On the one hand, using raw numbers instead of proportions prevents from a loss of information as for the number of observations that contribute to the proportion (Baayen, Davidson, & Bates, 2008). On the other hand, the model includes also random subject and item effects (Baayen et al., 2008; Jaeger, 2008), thus it enables the simultaneous analysis of both experimental fixed effects and individual and/or item (random) differences associated with them. Moreover, mixed models are robust than normality violations (Gelman & Hill, 2007).

[2]As reported in section 'Response coding' above, we considered as correct not only *wh*-questions with the typical order *Wh* V N, but also other strategies, such as clefted *wh*-questions, topicalized *wh*-questions, *wh*-questions introduced by *that*+NP instead of *which*+NP, *wh*-questions with missing subject, passive *wh*-questions.

Table 8. Estimated coefficients, standard errors, Z-values, and associated p-values for the group factor in the production of wh-questions with the constituent order WH V N.

Groups	Estimate	SE	Z	p
CI vs. CA	1.59314	0.69470	2.293	.022
CI vs. HE	1.57032	0.69414	2.262	.024

Table 9. Estimated coefficients, standard errors, Z-values, and associated p-values for the Group factor in the production of wh-questions with several structures.

Groups	Estimate	SE	Z	p
CI vs. CA	−0.9921	0.6157	−1.611	.107
CI vs. HE	−1.0140	0.6161	−1.646	.100

Table 10. Estimated coefficients, standard errors, Z-values, and associated p-values for the sentence type factor.

Sentence type	Estimate	SE	Z	p
Subject vs. object	0.8528	0.3731	2.286	.023

Table 11. Estimated coefficients, standard errors, Z-values, and associated p-values for the wh-element factor.

Wh-element	Estimate	SE	Z	p
Who vs. *which*+NP	1.050	0.3582	2.948	.003

Then, we focused on the wrong strategies used by the children in order to avoid the production of a *wh*-question. In order to avoid the instability of the model, we decided to group together "in situ" and "clitic pronoun" strategies into the variable 'Other strategies'. First of all, we considered as independent fixed factors GROUP (CI vs. CA, CI vs. HE), the dependent variable was the substitution of the *wh*-element (*who* instead of *which*+NP), and SUBJECT and ITEM were considered as random factors. Estimated coefficients, standard errors, Z-values, and associated *p*-values for GROUP are shown in Table 12.

As Table 12 shows, no significant difference between the CI group and the two control groups was found in the substitution of the *wh*-element, namely also typically developing children resorted to this strategy when a *which*+NP-question was elicited. After that, we considered the production of ungrammatical or incomplete sentences as the dependent variable. Results are shown in Table 13.

As shown by Table 13, children with CIs produced a higher number of ungrammatical or incomplete sentences than children of both control groups. Among the other wrong

Table 12. Estimated coefficients, standard errors, Z-values, and associated p-values for the group factor in the substitution of the wh-element.

Group	Estimate	SE	Z	p
CI vs. CA	0.4549	1.4514	0.313	.754
CI vs. HE	0.6455	1.4369	0.449	.653

Table 13. Estimated coefficients, standard errors, Z-values, and associated p-values for the group factor in the production of ungrammatical incomplete wh-questions.

Group	Estimate	SE	Z	p
CI vs. CA	−1.8548	0.7710	−2.406	.01614
CI vs. HE	−2.1851	0.8027	−2.722	.00648

strategies adopted by children from both the experimental and the control groups used to avoid the production of *wh*-questions are sentences in which the thematic roles were reversed. Table 14 shows the results of the statistical analysis carried out considering the inversion of the thematic roles as the dependent variable.

As shown by Table 14, no significant difference was found between the experimental and the control groups in the production of *wh*-questions with reversed thematic roles. Finally, we considered as dependent variable the use of other strategies, such as the production of "in-situ" questions or the production of *wh*-questions with a resumptive clitic pronoun. Results are shown in Table 15.

As shown by Table 15, no significant difference was found in the use of different incorrect strategies in order to avoid the production of a *wh*-question. For a deep analysis of the data collected from the CI group, also children with CIs' individual performance was analysed. Table 16 shows the CI children's individual performance presenting the proportion of raw scores of correct responses given for each sentence type.

Results show that all participants (with the exception of CI10) produced subject *who*-questions at ceiling. However, much variability was found in the production of the other sentence typologies. Indeed, while CI2 and CI9 produced at ceiling also subject *which* +NP-questions, and object *who* and *which*+NP questions, CI3 and CI6 showed only the asymmetry between *who* and *which*+NP questions, namely the production of the former structure is more preserved than the latter. The typical subject/object asymmetry was found in the performance of most participants, while some of them performed better on object *which*+NP-questions than subject *which*+NP questions.

Considering the mean of the correct responses in the control groups, we compared the performance of each child with CI to the performance of each of the control groups and we found that one of the ten children with CI out of 10 performed 1.5 SD below the mean

Table 14. Estimated coefficients, standard errors, Z-values, and associated *p*-values for the group factor in the production of *wh*-questions with reversed thematic roles.

Group	Estimate	SE	Z	p
CI vs. CA	−1.337	1.251	−1.069	0.285
CI vs. HE	−1.655	1.301	−1.271	0.204

Table 15. Estimated coefficients, standard errors, Z-values, and associated *p*-values for the group factor in the production of *wh*-questions resorting to other strategies.

Group	Estimate	SE	Z	p
CI vs. CA	−2.0522	1.2175	−1.686	0.0919
CI vs. HE	−1.1471	1.1104	−1.033	0.3016

Table 16. Individual CI children's performance in relation to their personal and clinical data (HA = hearing aid; CI = cochlear implant; HE = hearing experience).

					WHO		WHICH	
ID	Age	Age of HA	Age of CI	Length of HE	Subject	Object	Subject	Object
CI1	10;2	1;0	9;8	9;2	1.00	0.67	1.00	0.50
CI2	10;0	0;5	1;2	9;7	1.00	1.00	1.00	1.00
CI3	7;10	0;2	1;6	7;8	1.00	1.00	0.67	0.67
CI4	8;6	0;7	4;7	7;9	1.00	0.83	–	0.17
CI5	11;6	0;6	6;7	11;0	1.00	0.83	0.50	1.00
CI6	9;9	0;5	2;9	9;4	1.00	1.00	0.50	0.33
CI7	12;10	0;10	6;7	12;0	1.00	0.67	1.00	0.83
CI8	10;5	0;6	2;3	9;11	1.00	0.67	1.00	1.00
CI9	10;5	0;6	7;3	9;11	1.00	1.00	1.00	1.00
CI10	8;6	0;6	1;0	8;0	0.67	0.67	0.83	0.33

of correct subject *who*-questions. Four children of the ten children with CI out of 10 performed 1.5 SD below the performance of the control groups in the production of object *who* and *which*+NP questions. Five of the CI group out of 10 performed 1.5 SD below in the production of object *who*-questions.

We also run some correlation analyses in order to investigate whether a correlation exists between response accuracy and age of diagnosis and HAs fitting, and between accuracy and age of CIs fitting. Results showed that accuracy in the production of object *which*+NP-questions correlates with the length of use of HA (r = .654, p = .040), while accuracy in the production of object *who*-questions correlates with age of HAs fitting (r = .683, p = .029).

Discussion

Following previous studies (Volpato & D'Ortenzio, 2017, 2018), this study provides a more precise analysis of the production of subject and object questions introduced by *who* and *which*+NP in a group of 10 Italian-speaking children with CI. The performance of the experimental group was compared with the performance of two control groups matched on comparable chronological age (CA, 10 children), and a group matched on comparable length of exposure to oral language (HE, 10 children). The aim of the study was twofold. On the one hand, we aimed at analysing whether a difference exists between children with CI and children with normal hearing in the production of subject and object *wh*-questions. On the other hand, the purpose of this study was to analyse whether a correlation exists between clinical data (age of diagnosis, age of first HA, age of CI, length of hearing experience) and the response accuracy. Volpato and D'Ortenzio (2017) carried out a first pilot study comparing the performance of eight children with CI with a control group of eight children with normal hearing and comparable chronological age. Results showed the same tendencies in the production of *wh*-questions, namely both groups showed the typical subject/object asymmetry, and the *who*/*which*+NP asymmetry. Thereafter, Volpato and D'Ortenzio (2018) carried out a study with an increased number of participants, thus they compared the performance of a group of 13 children with CI with a control group of normal hearing children with comparable chronological age. The limit of these previous studies was the high heterogeneity of the experimental groups, since all children with CIs were included in the sample. For this study, we included only

children diagnosed and fitted with HAs within the first year of life. Indeed, as reported by Friedmann and Szterman (2006), the earlier the child receives the first HA fitting, the better will be his/her production and comprehension of complex syntactic structures.

In this study, we tried to provide a statistical analysis comparing the performance of children with CI to two control groups: one group was composed of children with typical language development and comparable chronological age; the other group included children with typical development and comparable length of exposure to oral language. The statistical analyses showed that children with CI performed significantly lower than both control groups, and that the experimental group produced a high number of ungrammatical or uncomplete sentences when a *wh*-question was elicited. Considering the results of the three groups overall, we found a significant difference between between subject and object *wh*-questions, namely the former are more accurate than the latter, and between *who* and *which*+NP-questions, the former being less difficult to produce than the latter. Finally, the correlation analyses showed that the age of HA fitting and the length of exposure to oral language was significantly positively correlated with the correct production of most complex structures, namely object *wh*-questions.

Children with CI vs. typically developing children

In this study, the group of children with CI performed significantly worse than the two control groups of children with typical language development matched on comparable chronological age (CA group) or on comparable length of exposure to the oral language (HE group). More in detail, children with CI showed lower performance in the production of object *who*-questions, and subject and object *which*+NP-questions. Assuming Friedmann and Szterman (2006), the worse performance of children with CI is caused by a syntactic deficit consisting in the wrong processing of syntactic movement when it leads to a sentence with a non-canonical order of constituents (i.e. *who* and *which*+NP object questions). However, as reported by Guasti et al. (2012) also children with typical language development struggle with the processing of sentences derived by movement of the object to a new position and resulting in a new sentence with a non-canonical order of constituents. Therefore, we may assume that the lower performance of the CI group compared to the two control groups may be caused by the delayed access to the linguistic input and, consequently, by a delay in the development of some syntactic skills, as also reported by Penke and Wimmer (2018), who retested a group of children with hearing loss after some years from the first assessment on the comprehension of *who*-questions.

Subject/object asymmetry

Overall the asymmetry between subject and object *wh*-questions was found significant, namely subject *wh*-questions are easier to perform than object *wh*-questions. Subject questions display an unmarked order of constituents (SVO in Italian); instead, object questions show a word order that is not canonical in Italian, since the object occupies a position at the beginning of the sentence and the subject is placed after the verb. Assuming Guasti et al.'s (2012) Agree Interference Approach (AIA), children find object *wh*-questions demanding because of an interference in the subject-verb agreement, which is crucial to interpret

whether a subject or an object *wh*-question is meant. As reported by Guasti and Rizzi (2002) and Frank, Lassi, Frauenfelder, & Rizzi (2006), agreement usually occurs in two steps: (i) AGREE is the operation whereby the subject transfers its person and number features to the verb before it moves to a new position in the sentence, and (ii) Spec-head agreement takes place after the subject has moved and is indispensable to verify whether subject and the verb still share the same person and number features. Therefore, while in subject *wh*-questions both AGREE and Spec-head agreement take place, in object *wh*-questions the subject-verb agreement is controlled only by AGREE because the subject does not move to a preverbal position. Consequently, agreement is checked only once in sentences with the Verb-Subject order, thus allowing interpreting errors. Therefore, children resort to several strategies in order to avoid the production of an object *wh*-question. For example, older children produce passive sentences which 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.

Who/which+*NP asymmetry*

The asymmetry between *who* and *which*+NP questions was find significant overall. Indeed, as found in previous studies (Friedmann & Szterman, 2006; Guasti et al., 2012, 2015; Volpato & D'Ortenzio, 2017, 2018), children performed better with *who*-questions than *which*+NP questions. Following Guasti et al. (2012, 2015) and Belletti and Guasti (2015) this asymmetry is caused by the complexity of the *which*+NP element, since the movement of the *wh*-element involves pied-piping of the nominal element (Belletti & Guasti, 2015). Moreover, also agreement relations are crucial for the correct interpretation of *which*+NP questions, since the *which*-phrase must agree with the NP that follows it. 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 & Guasti, 2015). The difficulties related to pied-piping can be supported by Jakubowicz's Derivational Complexity Hypothesis (DCH, Jakubowicz, 2004, 2005, 2011), who states that children acquire less complex structures first. Indeed, complexity is measured by the Derivational Complexity Metric (DCM, Jakubowicz, 2005, 2011):

- Merging α n times gives rise to a less complex derivation than merging α (n + 1) times.
- Internal merge of α gives rise to a less complex derivation than internal merge of α + β.

Therefore, according to the second clause of DCM, children initially prefer structures where only one constituent is involved in the movement to a new position, namely *who*. This hypothesis is supported by the strategies adopted by children with CI to avoid the production of *which*+NP-questions, namely they asked questions introduced by *who* instead of *which*+NP.

Correlation between clinical data and response accuracy

Early intervention on hearing loss ensures better performance of children in highly complex syntactic structures. This was pointed out by several studies (Friedmann & Szterman, 2006; Geers, Moog, Biedenstein, Brenner, & Hayes, 2009; Guasti et al., 2012; Johnson & Goswami, 2010; Moeller, 2000; Oller & Eilers, 1988; Schauwers et al., 2005; Yoshinaga-Itano et al., 2010). Moreover, it has been found that infants who are diagnosed early, even at birth, and receive hearing aids (HA) within the ninth month of life can reach good performances across a range of communication skills (Ambrose et al., 2014; Caselli et al., 2012; Watkin et al., 2007; Yoshinaga-Itano, 2003). We selected only children who received the first HA within the first year of life. We then investigated the relationship between this clinical variable with the accuracy of the responses and we found that children who received early intervention performed better in the production of object *wh*-questions. These findings confirm previous studies assuming that early intervention allow children to reach high performances in the processing of complex syntactic structures (Friedmann & Szterman, 2006).

Conclusion

Concluding, this study confirms the results of previous studies, namely children (either with CI or normal hearing) show two asymmetries when processing *wh*-questions: (i) the subject/object asymmetry, and (ii) the *who*/*which*+NP asymmetry. Moreover, this study confirms that children with normal hearing perform better than children with CI. Finally, also early intervention on hearing loss and length of use of hearing devices have been found crucial for the development of appropriate syntactic abilities.

Acknowledgments

We are grateful to the children and the families who participated in this study. We would like to thank the team members of the Ear, Nose, Throat Clinic of the University of Padua for their essential collaboration. We are also grateful to the audience of the ICPLA 2018 for their feedback, the two anonymous reviewers for their comments and to Giorgio Arcara for his helpful suggestions for the statistical analysis.

Declaration of interest

The authors report no conflicts of interest.

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