Listening Difficulties of Children With Cochlear Implants in Mainstream Secondary Education

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Objectives: Previous research has shown that children with cochlear implants (CIs) encounter more communication difficulties than their normal-hearing (NH) peers in kindergarten and elementary schools. Yet, little is known about the potential listening difficulties that children with CIs may experience during secondary education. The aim of this study was to investigate the listening difficulties of children with a CI in mainstream secondary education and to compare these results to the difficulties of their NH peers and the difficulties observed by their teachers.

Design: The Dutch version of the Listening Inventory for Education Revised (LIFE-R) was administered to 19 children (mean age = 13 years 9 months; SD = 9 months) who received a CI early in life, to their NH classmates (n = 239), and to their teachers (n = 18). All participants were enrolled in mainstream secondary education in Flanders (first to fourth grades). The Listening Inventory for Secondary Education consists of 15 typical listening situations as experienced by students ($LIFE_{student}$) during class activities ($LIFE_{class}$) and during social activities at school ($LIFE_{social}$). The teachers completed a separate version of the Listening Inventory for Secondary Education ($LIFE_{teacher}$) and Screening Instrument for Targeting Educational Risk.

Results: Participants with CIs reported significantly more listening difficulties than their NH peers. A regression model estimated that 75% of the participants with CIs were at risk of experiencing listening difficulties. The chances of experiencing listening difficulties were significantly higher in participants with CIs for 7 out of 15 listening situations. The 3 listening situations that had the highest chance of resulting in listening difficulties were (1) listening during group work, (2) listening to multimedia, and (3) listening in large-sized classrooms. Results of the teacher's questionnaires ($LIFE_{teacher}$ and Screening Instrument for Targeting Educational Risk) did not show a similar significant difference in listening difficulties between participants with a CI and their NH peers. According to teachers, NH participants even obtained significantly lower scores for staying on task and for participation in class than participants with a CI.

Conclusions: Although children with a CI seemingly fit in well in mainstream schools, they still experience significantly more listening difficulties than their NH peers. Low signal to noise ratios (SNRs), distortions of the speech signal (multimedia, reverberation), distance, lack of visual support, and directivity effects of the microphones were identified as difficulties for children with a CI in the classroom. As teachers may not always notice these listening difficulties, a list of practical recommendations was provided in this study, to raise awareness among teachers and to minimize the difficulties.

Key words: Academic achievement, Audiology, Cochlear Implants, Inclusion, Listening skills, Long-term outcomes, Mainstream school, School performance, Speech perception, Rehabilitative Audiology

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INTRODUCTION

Universal newborn hearing screening has led to early diagnosis of hearing loss in newborns, which facilitates clinical intervention and treatment at an earlier age. Early intervention, with hearing aids or cochlear implants (CIs), allows the child to access auditory stimulation at the beginning of their speech and language development, which is beneficial for the development of their auditory receptive skills, linguistic skills, and speech intelligibility (Geers 2006; Wie et al. 2007; Geers et al. 2008; Baudonck et al. 2010; Boons et al. 2012; Ching 2015; Ching et al. 2018; Yoshinaga-Itano et al. 2018).

While the importance of early implantation has long been recognized, the definition of early implantation has changed over the years. In the beginning of pediatric cochlear implantation, implantation was considered early before the age of 3.5 years—that is, the cutoff age for the sensitive period of auditory development as measured with cortical potentials (Sharma et al. 2002, 2007). However, as the Food and Drug Administration approved earlier implantation, the implantation age has dropped systematically. In the early 2000s, centers started implanting at 2 years or younger, resulting in even better outcomes at preschool age (e.g., Govaerts et al. 2002; Rubinstein 2002; Svirsky et al. 2004; Tait et al. 2007; Hayes et al. 2009; Philips et al. 2009; Boons et al. 2012). In the last decade, age at implantation has dropped even further, and many countries now provide CIs below the age of 1 year. Evidence is now accumulating that implantation before 1 year of age would have an additional beneficial effect on the receptive and expressive language skills of the child (e.g., Schauwers et al. 2004; Houston & Miyamoto 2010; May-Mederake 2012; Leigh et al. 2013; Nicholas & Geers 2013; Dettman et al. 2016; Ching et al. 2017; Miyamoto et al. 2017; Mitchell et al. 2019; for systematic reviews, see Bruijnzeel et al. 2016; McKinney 2017). However, not all of the early implanted children are able to obtain age-appropriate outcomes. Even in the early implanted group, the reported variability remains substantial (van Wieringen & Wouters 2015). Moreover, longitudinal studies with larger sample sizes are needed to confirm the additional benefit of early implantation in the long term (Bruijnzeel et al. 2016). In addition, comorbidities and development disorders are often considered as exclusion criteria in follow-up studies, resulting in biased information about the overall outcome expectations after early cochlear implantation.

Nevertheless, the general increase of the spoken language abilities has led to a higher participation of children with CIs in mainstream schools (Huber et al. 2008; Venail et al. 2010). Over the years, better learning outcomes were reported for oral language, reading, writing, and mathematics (e.g., Sarant et al. 2015). These reported results were, however, still lower than the results of normal-hearing (NH) peers. Furthermore, studies that confirm good outcomes in the long term, for instance, in secondary or tertiary education, are sparse in literature. The limited body of research including this particular group of CI users shows that difficulties can still come to expression later in life, despite achieving age-appropriate skills in their early academic career (Geers et al. 2016; Blom et al. 2017; Crowe et al. 2017). Difficulties reported in these studies were mostly related to complex language abilities and advanced literacy skills when they are 11 to 16 years old (Geers et al. 2016; Nittrouer et al. 2018). Other studies on older CI users have focused on more general educational placement, while exploring possible predictors explaining the variability found in the long-term outcome results. The variability—or at least part of it—is in most cases attributed to multiple factors, including age at implantation, speech and language outcomes, communication mode, parental support, socioeconomic background, CI programming and device characteristics, unilateral or bilateral CI use, cognitive abilities, and other developmental disorders (Spencer et al. 2004; Thoutenhoofd 2006; Vermeulen et al. 2007; Geers et al. 2008; Robinson et al. 2012; Casserly & Pisoni 2013; Desloovere et al. 2013; Edwards et al. 2016; Illg et al. 2017).

Another important factor that could have a major impact on their school functioning is the acoustical environment at school (Busch et al. 2017). The acoustical environment at school is characterized by high levels of background noise and reverberation (Crandell & Smaldino 2000), which are both highly disruptive for speech understanding, particularly for children with CIs (Neuman et al. 2012; Caldwell & Nittrouer 2013; Iglehart 2016). In mainstream education, teaching activities are predominantly auditory-oral resulting, children with CIs are at risk of missing information when these acoustical challenges occur.

The first signs of acoustical and educational challenges are often contained in subtle communication irregularities, such as misconceptions and misunderstandings (e.g., Terwogt & Rieffe 2004), which are often hard to notice during daily (school) activities (also stated by Vermeulen et al. 2012). Moreover, mainstream teachers are often not trained to educate children with hearing problems; therefore, these subtle communication difficulties remain unnoticed in school (De Raeve & Lichtert 2012). To optimize the success of the heterogeneous group of children with CIs in mainstream schools, their individual challenges should be monitored closely (Mellon et al. 2016). One possible method to screen for their challenges in the classroom is by using questionnaires and screening tools. Different questionnaires and tools were developed for teachers to assess the functioning of children with hearing impairment in school, such as the Teacher Evaluation of Auditory/oral performance of Children (Ching et al. 2008), the Teacher Evaluation of Auditory Performance (Purdy et al. 2002), and the Screening Identification for Targeting Educational Risk (SIFTER; Anderson 1989).

The SIFTER contains 5 different content areas, namely academics, attention, communication, participation, and behavior. The combination of content areas makes it particularly interesting because it includes both educational and communicational challenges. Damen et al. (2006) used the SIFTER to investigate the school functioning of children with a CI (implanted before the age of 5) in kindergarten and mainstream elementary schools. They found that children with a CI scored as well as their NH peers for all content areas, except on communication.

Moreover, the communicational difficulties are likely to increase when children with CIs make the transition to secondary school, due to the increased complexity of the content taught (Archbold 2015), the greater level of participation required for class activities (e.g., class discussions; Punch & Hyde 2010), the lack of visual support (Blom et al. 2017), and the number of different teachers (De Raeve 2015). An ideal tool to use in secondary education is the Listening Inventory for Education Revised (LIFE-R, Anderson et al. 2011). The LIFE-R questionnaire thoroughly assesses potential listening difficulties in the classroom, and it includes both a teacher and student appraisal. The LIFE-R can also be used as an evaluation tool for classroom interventions in pretest and posttest conditions. In this format, the LIFE-R was used in a few recent studies to measure the effectiveness of a specific intervention—for instance, for the evaluation of electrical acoustic stimulation (Silva et al. 2017) and Frequency Modulating systems (Wolfe et al. 2015), though both of these studies only included the teacher appraisal. Zanin and Rance (2016) assessed the benefit of hearing assistive technology (HAT) in adolescents in mainstream education (12–18 years) with both teacher and student appraisal. They compared the reported listening difficulties in 2 conditions: with CIs or hearing aids only (pretest condition) and with the additional use of HAT (posttest condition). For every condition, a total sum score (%) was calculated for the LIFE-R questions. Results showed that considerably more listening difficulties (lower LIFE sum score) were reported in the pretest condition compared with the posttest condition (mean LIFE sum score of 49.6% versus 70.8%).

As the LIFE-R seems to be a sensitive tool for identifying listening challenges in classrooms, our research group has recently translated and validated the LIFE-R into Dutch (Krijger et al. 2018). In Belgium, up to 66% of the children with a CI are enrolled in secondary education (De Raeve 2015). From this population, a group of early implanted children was recruited for the present study.

The main objectives of the present study were the following: (1) to explore the listening difficulties of early implanted children with CIs in mainstream secondary education, (2) to investigate whether children with CI have more listening difficulties than their NH peers, and (3) to determine whether the teachers are able to identify the child-specific listening difficulties. We hypothesized that children with a CI would report more listening difficulties in the acoustically challenging listening situations than their NH peers. Also, we hypothesized that teachers would have problems identifying these listening difficulties given their subtle nature.

Our secondary aim was to examine the impact of HAT on the child's listening difficulties, as we hypothesized that this would decrease the experienced listening difficulties. Thirdly, we aimed at giving an impetus for validating the sum scores of the LIFE questionnaires and at providing a list of common experienced difficulties, including an acoustical characterization of the difficulty as well as possible recommendations to minimize the experienced difficulty.

MATERIALS AND METHODS

Participants

Participants With CIs • For participants with a CI, the inclusion criteria were the following: (1) having received the first CI before the age of 2 and (2) attending mainstream secondary education. Information letters were sent to eligible participants with CIs from the databases of the Ear, Nose, Throat Department of the University Hospital of Ghent (n = 10, $n_{included}$ = 10) and the

Eargroup, Deurne, Antwerp (n = 10, $n_{included}$ = 8). Of these, 1 participant declined participation, and another participant was unable to fill out the questionnaire due to severe autism.

In addition, information letters were sent to all rehabilitation centers in Flanders (i.e., the Northern part of Belgium) and to parents of participants with a CI from the "Flemish association for parents of children who are hard of hearing or deaf" (VLOK-CI [Vlaamse vereniging voor ouders van dove en slechthorende kinderen]), which resulted in 1 additional participant from VLOK-CI.

In total, 19 participants with a CI were included in this study (mean age = 13 years 9 months; SD = 9 months). Their mean age of implantation was 1 year and 1 month of age (SD = 3 months). Nine of them were implanted unilaterally, of whom 3 had contralateral residual hearing augmented with a hearing aid (bimodal). The other 10 participants were implanted bilaterally with a mean interval of 3 years 2 months (SD = 3 years 1 month; range = 1 month to 8 years 8 months) between the first and second implantation. In Figure 1, the speech perception scores (phonemes scores in quiet) of the participants are depicted with their first CI, second CI, or contralateral hearing aid (Fig. 1). These data were retrieved from their last fitting session.

All participants with a CI attended different secondary schools across Flanders, from the first to the fourth grades (see Table 1 for the distribution of the type of schools and grades). They relied on the support of peripatetic teachers (i.e., teachers of special education who support children in mainstream schools, n = 19), on the support of a notetaker (n = 1), and on the support of HAT (n = 8).

Demographic details concerning etiology of deafness, age at implantation, listening modality, educational setting, and the use of support in class were listed in Table 1.

NH Participants • In total, 239 NH classmates of the participants with CIs took part in this study (mean age = 13 years 9 months; SD = 10 months). They were enrolled in first grade (n = 88), second grade (n = 77), third grade (n = 36), and fourth grade (n = 46). NH participants were included if no hearing difficulties were reported by their parents and teachers. In Flanders, school-aged children receive hearing screenings in elementary schools and secondary schools, which are organized by the health and service centers. Screenings are performed at the age of 6 to 7 years, 10 to 11 years, and 14 to 15 years (Denys et al. 2018). For the included group, no hearing difficulties were reported.

Main Class Teachers • For every child with a CI (n = 19), the main class teacher participated in this study. Class teachers are teachers who are assigned to a particular class to monitor the individual student progress. One class teacher was not able to fill out

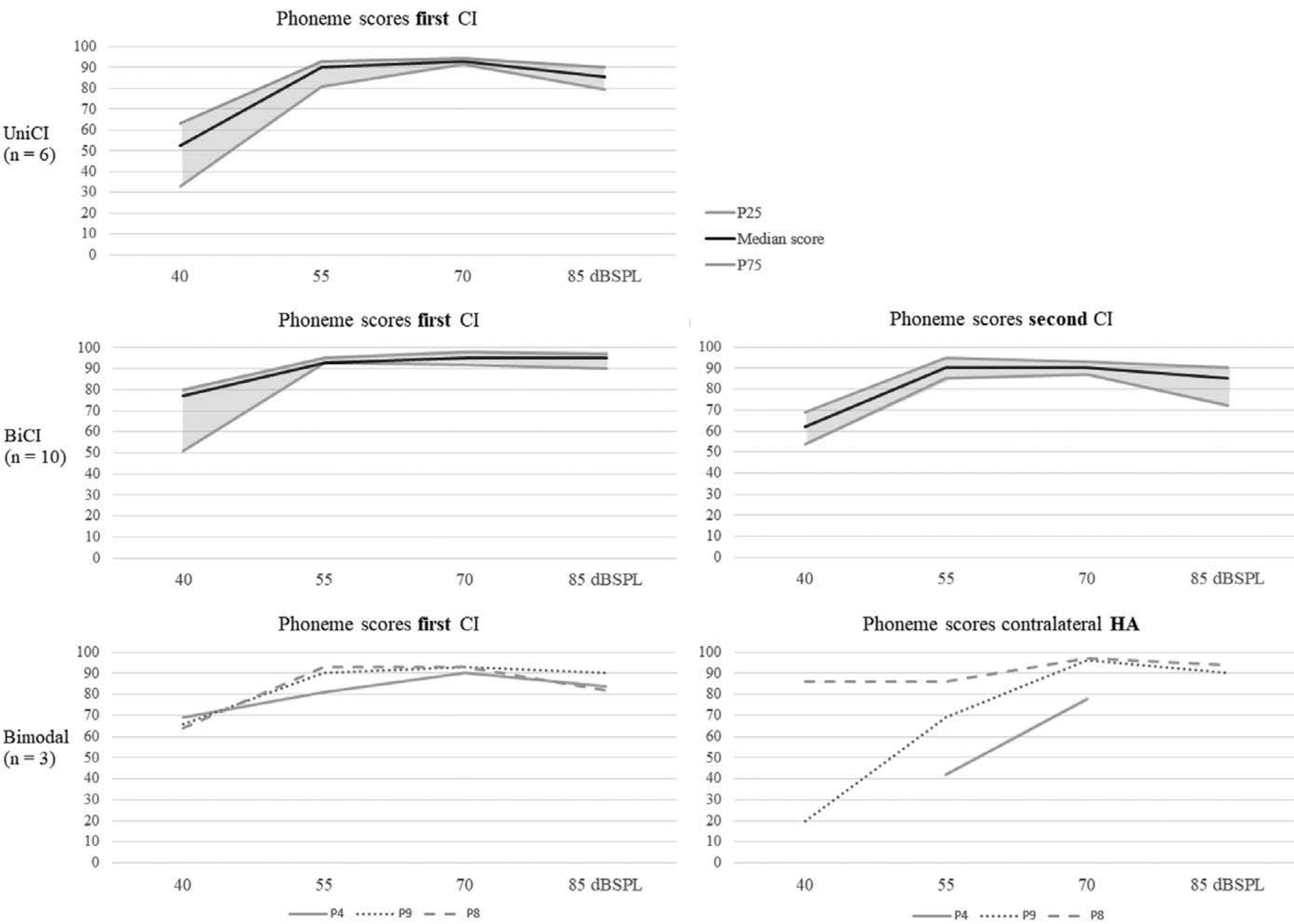

Fig. 1. Mean phoneme scores (consonant vowel consonant words) of participants with a unilateral CI (n = 6), bilateral CIs (n = 10), and bimodal hearing modality (n = 3). For participants with a UniCI and BiCIs, the median scores (black line) and interquartile ranges (gray area) are represented. For the 3 bimodal participants, the individual data are plotted. BiCI, bilateral CI; CI, cochlear implant; UniCI, unilateral CI; HA, hearing aid.

TABLE 1. Patients Demographics

Subject	Age (y; m)	Etiology of Deafness	Hearing Modality	Age of Implantation (y; m)	Interimplant Delay (y; m)	Grade	School Type	HAT
1	12; 6	Cx26	BiCI	0; 9	1; 5	1	B	RM
2	12; 7	CMV	BiCI	0; 5	0; 8	1	B	RM
3	13; 1	Unknown	BiCI	0; 8	3; 4	1	A*	
4	13; 2	Cx26	Bimodal	1; 2		1	A*	
5	13; 3	Cx26	BiCI	0; 8	5; 8	1	B	RM
6	13; 8	CMV	UniCI	1; 3		1	A*	RM
7	14; 2	Cx26	BiCI	1; 0	8; 8	1	B	
8	13; 1	Unknown	Bimodal	1; 3		2	A*	RM
9	13; 2	Meningitis	Bimodal	1; 2		2	A*	
10	13; 4	Unknown	UniCI	1; 0		2	A*	RM
11	13; 8	Cx26	BiCI	0; 8	1; 4	2	A*	
12	14; 1	CMV	BiCI	0; 9	0; 8	2	A*	
13	14; 2	CMV	BiCI	1; 3	1; 9	2	A*	RM
14	14; 4	Cx26	UniCI	1; 8		2	B	
15	13; 8	Meningitis	UniCI	1; 8		3	T	
16	14; 6	Meningitis	UniCI	1; 4		3	T	RM
17	15; 4	Unknown	BiCI	0; 7	0; 1	3	G	
18	15; 6	Unknown	BiCI	1; 5	7; 1	4	G	
19	15; 9	Waardenburg	UniCI	1; 3		4	G	

**In first and second grades, two school types are used: A-stream (A) and B-stream (B). From the third grade on A-streamed children can choose for General or Technical education, whereas B-streamed children can choose between Technical and Vocational education.*
A, A-stream; B, B-stream; BiCI, bilateral CI; CI, cochlear implant; CMV, cytomegalovirus; Cx26, connexin 26; G, general education; HAT, hearing assistive technology; RM, remote microphone; T, technical education (Dutch "TSO"); UniCI, unilateral CI; V, vocational education.

the questionnaires due to time constraints. If a class teacher had a limited educational assignment for the respective participant with a CI (i.e., less than 3 hours a week, n = 3), the questionnaires were filled out with the help of several of his/her colleagues.

Informed Consent

This study was approved by the Ethics Committee of the Ghent University Hospital.

All participants, as well as the parents of participants with CIs, signed informed consent to participate in this study and to collect demographical and audiological data. Parents of the NH participants received an opting-out letter 1 week before administering the questionnaires in the classroom. Three parents did not give their consent for their NH child to participate in the study due to "high workload."

Materials

Listening Inventory for Secondary Education • The Dutch translation of the Listening Inventory for Secondary Education (LIFE2-NL) was used for all participants (see Appendix A in Supplemental Digital Content 7, http://links.lww.com/EANDH/A617). For details of the translation process of the original LIFE-R (Anderson et al. 2011), we refer the reader to Krijger et al. (2018).

The LIFE2-NL includes a student and a teacher appraisal.

The student appraisal comprised the Before LIFE2-NL, the LIFE2-NL for Students, and the After LIFE2-NL. The Before LIFE2-NL describes the listening environment of the student by means of six multiple-choice questions. The LIFE2-NL for Students evaluates the difficulty of 15 typical listening situations in school on a 5-point Likert scale (10-7-5-2-0, 0 for "always challenged" up to 10 for "no challenge"). Listening situations 1 to 10 describe classroom activities (subscore LIFE$_{class}$), and listening situations 11 to 15 describe social listening situations in school (subscore LIFE$_{social}$). In total, 150 points could be obtained (LIFE$_{student}$). The After LIFE2-NL describes the student's listening strategies by means of six multiple-choice questions.

The teacher appraisal comprised the LIFE2-NL for Teachers and the Self-advocacy skills checklist. The LIFE2-NL for Teacher evaluates similar classroom situations as the student version and uses the same scoring (total of 150 points, LIFE$_{teacher}$). The Self-Advocacy checklist assesses to what extent participants with a CI communicate their listening needs in the classroom on a 5-point Likert scale (8 self-advocacy skills with a maximum score of 80 points).

Screening Instrument for Targeting Educational Risk • The SIFTER consists of 15 questions about 5 content areas: academics, attention, communication, class participation, and school behavior. Each content area comprised 3 questions, of which the response had to be filled out on a 5-point Likert scale (1-2-3-4-5).

Administration of the Questionnaires

The NH participants and participants with a CI filled out the student appraisal of the LIFE2-NL. Participants with a CI did this during a semistructured interview. They were given 1 hour approximately to fill out the questionnaires. Afterward, interviewers could ask additional questions regarding their experiences in class and their support in class. NH participants filled out the questionnaires during appropriate moments in class, chosen by their class teachers. Questions related to hearing loss or hearing devices were omitted for NH participants (highlighted in Appendix A in Supplemental Digital Content 7, http://links.lww.com/EANDH/A617).

The class teachers filled out 2 questionnaires, namely the teacher appraisal of the LIFE2-NL and the SIFTER. They did this for the participants with a CI (n = 18) as well as for one of the NH classmates of the participant with a CI. The NH participant was selected based on his or her own $LIFE_{student}$ score (median of the class), to ensure that he or she would reflect a "mean performer" in class.

Validity and Scoring Method of the Questionnaires

The SIFTER was used in previous studies (Dancer et al. 1995; Damen et al. 2006; Damen et al. 2007; Wu et al. 2013) and has shown to be a sensitive tool to screen for educational risks in mainstream schools. The SIFTER scores are obtained by summing the responses of the 3 questions in each content area. This summed score can then be plotted on a scoring grid, which indicates if it is sufficient, marginal, or failure. As a result, a risk profile of the student can be made.

In a previous study, the original LIFE-R was first translated to Dutch (LIFE2-NL) and this translation was then thoroughly validated (content validity, concept validity, and cross-cultural validity; see Krijger et al. 2018). The LIFE2-NL was also checked on its reliability and internal consistency by means of the Cronbach alpha coefficient (0.86 for $LIFE_{student}$, 0.89 for $LIFE_{class}$, and 0.75 for $LIFE_{social}$). The present study sought to further validate the total sum score and its subscores, following the same methodology used in the SIFTER, using a scoring grid. This scoring grid was based on the normative data (percentile scores) of the NH participants and includes 4 categories. The categories were labeled as representing "Easy listening," "Average listening," "Minor listening difficulties," and "Major listening difficulties." Based on these categories, a "Listening profile" for the students was developed, which gives an indication of their functional listening in class. The "Listening profile" can also be used to understand the severity of the experienced listening difficulties of the participants with CIs, relative to their NH peers. A visual overview of the questionnaires, scores, subscores, and categories are shown in Figure 2. This overview will also be the framework for subsequent statistical analyses.

Statistical Analysis

Statistical analyses were performed with IBM SPSS statistics version 25.0 (SPSS Inc., Chicago, Illinois). Results were considered statistically significant for p values <0.05.

LIFE2-NL for Students • *Descriptive Statistics and Cutoff Values Scoring Grid* • Median scores and interquartile ranges were calculated for the 15 LIFE2-NL questions, for the total sum score ($LIFE_{student}$), and for the subscores separately ($LIFE_{class}$, $LIFE_{social}$). Of the NH data percentiles, P2.5, P25, P50, and P75 were calculated for $LIFE_{student}$, $LIFE_{class}$, and $LIFE_{social}$ to obtain the cutoff values for the 4 categories in the scoring grid: "Easy listening" (>P75), "Average listening" (P75–P25), "Minor listening difficulties" (<P25–P2.5), and "Major listening difficulties" (<P2.5). Frequency tables were made with the number of NH participants and participants with a CI who scored within all 4 categories.

Comparisons Between Participants With a CI and Their NH Peers • To account for the clustering within school, binary mixed logistic regression analyses, with school as the random factor, were applied to estimate the percentage of students who report listening difficulties in each group (NH versus participants with a CI). These analyses were performed with a dichotomous dummy code, which divided the outcome results into "no listening difficulties" (=0) versus "listening difficulties" (=1, see overview Figure 2). For the separate LIFE2-NL questions, 0 and 2 responses were coded as "listening difficulties"

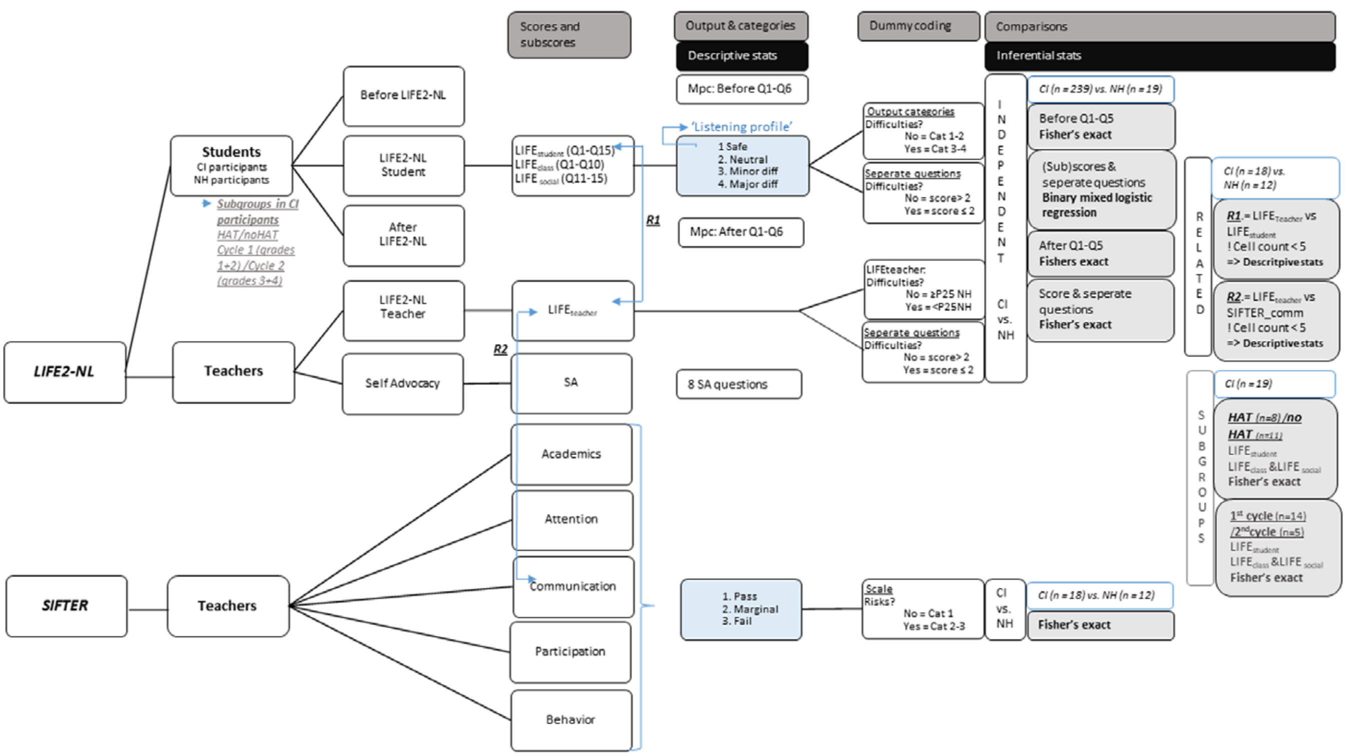

Fig. 2. Overview of methodology: scores, categories, and statistics. LIFE, Listening Inventory for Education; LIFE2-NL, Listening Inventory for Secondary Education; SA, Self-Advocacy; SIFTER, Screening Instrument for Targeting Educational Risk.

and 5-7-10 responses as "no listening difficulties." For $LIFE_{student}$, $LIFE_{class}$, and $LIFE_{social}$, minor and major listening difficulties were coded as "listening difficulties" and easy and average listening as "no listening difficulties." The model was applied to the sum score (and its subscores) and the 15 questions of the LIFE2-NL for Students, where sufficient participants were represented in the categories (n > 5, which was not the case in Q1). In addition, significant results of the model were validated using logistic regression with bias-corrected accelerated bootstrap validation (Babyak 2004). Results of the Before LIFE2-NL and After LIFE2-NL were represented in frequency tables. Differences in frequencies between the NH and CI group were analyzed with the Fisher exact test, for questions 1 to 5 (if the frequency >5).

Comparisons Within Participants With a CI • Within the group of participants with a CI, 2 different subgroups were analyzed. The first subgroup was created based on the use and nonuse of HAT. The second subgroup was created based on the "cycle" in which the participants were enrolled. In Belgium, the first and second grades of secondary school are defined as first cycle, whereas third and fourth grades are defined as second cycle. Of these subgroups, the percentages of participants in the 4 outcome categories (for the $LIFE_{student}$ score and its subscores) were compared with each other by means of a Fisher exact test.

LIFE2-NL for Teachers • ***Descriptive Statistics*** • For every question (Q1–Q15) of the LIFE2-NL for Teachers, median scores and interquartile ranges were calculated for NH participants and participants with a CI.

For the participants with a CI, median scores and interquartile ranges were calculated for the 8 questions of the self-advocacy questionnaire (Q1–Q8).

Comparisons Between Participants With a CI and Their NH Peers • A Fisher exact test was used to compare the $LIFE_{teacher}$ and the separate questions of the teacher appraisal between groups (NH and CI group). Analog to the LIFE2-NL for Students, a dichotomous dummy code was used, by which 0 and 2 responses were coded into "listening difficulties" and 5-7-10 responses to "no listening difficulties." In addition, the total sum scores ($LIFE_{teacher}$) of participants with a CI were coded as listening difficulties if they were below the interquartile range of NH participants. Further analyses with the mixed logistic regression were not performed for the teacher appraisal due to the small sample size.

Related Comparisons • Related comparisons were made between the scores of the $LIFE_{student}$ and $LIFE_{teacher}$ and the scores of the $LIFE_{teacher}$ and communication content area of the SIFTER. These comparisons were based on the number of participants experiencing listening difficulties (Minor/Major on LIFE2-NL) or communicational risks (Fail/Marginal on SIFTER). Due to the small cell count in these related comparisons (cell counts < 5), no further statistical analysis was performed.

Screening Instrument for Targeting Educational Risk • ***Comparisons Between NH Participants and Participants With a CI*** • A Fisher exact test was used to compare the 5 content areas of the SIFTER between groups (NH and CI group). Equivalent to the LIFE2-NL Teacher appraisal, a dichotomous dummy code was used, by which the fail and the marginal categories were coded as "listening difficulties" and the pass category was coded into "no listening difficulties."

RESULTS

LIFE2-NL for Students

The results of the LIFE2-NL for students pertained to the listening difficulties of children with a CI in mainstream classes. Their results were compared with their NH classmates, by means of descriptive statistics and inferential statistics on the frequency tables of the scoring grid. In addition, the Before and After LIFE2-NL of the appraisal were compared between groups. Lastly, subgroup comparisons were performed to investigate the effect of HAT and school grade on the reported listening difficulties within the CI group.

Descriptive Statistics • Participants with a CI achieved lower median scores on the total $LIFE_{student}$ (86; interquartile range = 77–98) and its subscores, $LIFE_{class}$ (59; 50 to 70) and $LIFE_{social}$ (29; 19 to 29), compared with their NH peers, who achieved 108 (95–122), 72 (64–82), and 35 (31–41), respectively. The median scores and interquartile scores of the 15 separate listening situations are shown in Figure 3 for both CI and NH participants. Based on the percentile scores of the NH participants, cutoff values for the 4 categories "Easy listening," "Average listening," "Minor listening difficulties," and "Major listening difficulties" were defined as part of the scoring grid and are represented in light gray (Table A in Supplemental Digital Content 1, http://links.lww.com/EANDH/A613). The percentages of participants scoring in these 4 categories are represented in Figure 4.

Comparisons Between Participants With a CI and Their NH Peers • Based on the $LIFE_{student}$ scores, significantly more participants with CIs reported minor and major listening difficulties (68.4%), when compared with their NH peers (23.4%) ($p < 0.006$). The percentages of participants reporting difficulties also differed across groups when comparing the subscales: $LIFE_{class}$ (63.2% [CI] versus 24.7% [NH]; $p < 0.001$) and $LIFE_{social}$ (52.6% versus 23.0%; $p = 0.001$).

The regression model generated estimated percentages of participants experiencing minor and major listening difficulties. The model estimated that 75.1% (95% confidence interval = 48.8%–90.5%) of the participants with CIs were experiencing listening difficulties, compared with only 23.0% (17.3%–29.8%) of the NH participants. Of the NH participants, 23.8% (17.9%–30.9%) were likely to report listening difficulties in class ($LIFE_{class}$), and 23.1% (17.9%–29.3%; $LIFE_{social}$) were likely to experience listening difficulties during social activities in school ($LIFE_{social}$). Participants with a CI were more likely to experience difficulties, of which 62.6% (37.2%–82.5%) in class ($LIFE_{class}$) and 56.3% (32.2%–77.7%) difficulties during social activities ($LIFE_{social}$). Moreover, when participants with CIs experienced difficulties in class, the difficulties were always labeled as minor, whereas when they occurred in social activities, 39.6% of the total reported difficulties fell within the major category (21% minor versus 32% major, see Fig. 4).

Median scores and interquartile scores of the 15 individual LIFE2-NL questions are shown in Table 2. Participants with a CI reported significantly more listening difficulties than their NH peers for "Listening to the teacher with back turned" (Q2, $p = 0.041$), "Listening to a student answering during discussion" (Q4, $p = 0.019$), "Listening to multimedia" (Q8, $p = 0.002$), "Listening during group work" (Q11, $p < 0.001$), "Listening in gym class" (Q12, $p = 0.003$), and "Listening during informal social times" (Q15, $p = 0.004$). The regression model

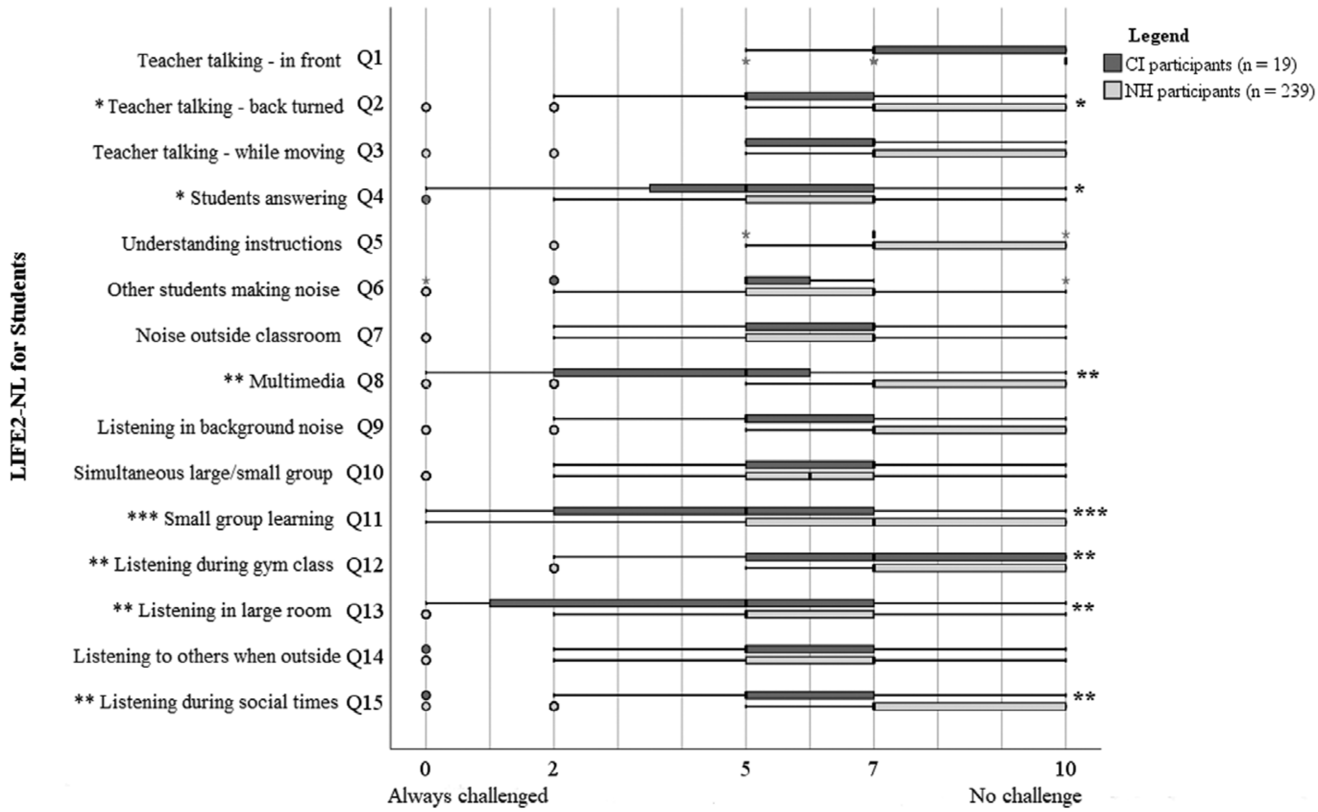

Fig. 3. LIFE2-NL for Students. The box plots represent the median scores and interquartile scores of the 15 LIFE2-NL questions. Significant differences between groups (NH vs. CI) are marked by an asterisk (*$p < 0.05$; **$p \leq 0.01$, ***$p \leq 0.001$). CI, cochlear implant; LIFE2-NL, Listening Inventory for Secondary Education; NH, normal hearing.

generated estimated percentages of participants who experienced these listening difficulties. These percentages are listed adjacent to the *p* values in Table 2. For all variables, significant results from Table 2 were confirmed with a bias-accelerated bootstrap validation ($p < 0.05$). The highest 3 percentages in the CI group were estimated for “Listening during group work” (Q11, 43.6%, 95% confidence interval = 21.4%–68.8 %), “Listening to multimedia” (Q8, 31.3%, 13.6%–56.9%), and “Listening in large rooms” (Q13, 31.3%, 13.6%–56.9%).

Below, the main results of the Before and After LIFE2-NL were summarized (detailed results can be found in Table B in Supplemental Digital Content 2, http://links.lww.com/EANDH/A614 and Table C in Supplemental Digital Content 3, http://links.lww.com/EANDH/A615). In the Before LIFE2-NL, the listening situation and location of CI students were compared with those of their NH peers. Significant differences were found between CI and NH participants for “Positioning in classroom” (Q1), “Understanding the teacher” (Q3), and “Knowing when the teacher was not understood” (Q5). The differences are reported in detail below. Concerning the positioning in classroom (Q1), the majority of participants with a CI indicated they were seated in front row position (85%) compared with 44% of the NH participants ($p = 0.001$). The majority of the NH participants were seated in the middle row (39%, $p = 0.013$) or back row position (30%, $p = 0.017$). Of the participants with a CI, 2 preferred to sit in the middle of the classroom, and 1 CI student was obliged to sit at the back of the classroom due to practical and logistical considerations (use of a notetaker). In 2 schools, desks were rearranged in a “U” form to ensure optimal visual input for the CI student. More NH participants than participants with CIs indicated that they “always” hear the teacher well (Q3; 65% versus 26%, $p = 0.001$), whereas more participants with CIs than NH participants indicated they hear almost everything (74% versus 44%, $p = 0.015$). More participants with CIs than NH participants reported that when they realized they had not understood the teacher completely and they had to look at the teacher’s lips (Q3; 53% versus 2%, $p < 0.001$).

In the After LIFE2-NL, differences were investigated between the NH group and CI group, concerning their behavior toward the experienced listening challenges. Significant differences were found between participants with a CI and NH participants for “Letting the teacher know that the instruction was not understood” (Q1), “Letting the teacher know it is too noisy in the classroom” (Q2), and “Letting the teacher know that another student has not been understood during class discussion” (Q3). These differences are reported below.

Participants with a CI were more inclined than their NH peers to talk to the teacher after class when they had not understood their teacher well (Q1, 26% versus 4%, $p = 0.002$). When it is too noisy in class, more participants with CIs than NH participants would raise their hand to let the teacher know (Q2, 63% versus 38%, $p = 0.049$) or would talk to the teacher after class (21% versus 5%, $p = 0.027$). Half of the NH students would rather do nothing and put more effort into their listening (46%). When a student is not understood in a class discussion, more participants with CIs than NH participants would turn around to see the face of the student (Q3, 95% versus 45%, $p < 0.001$).

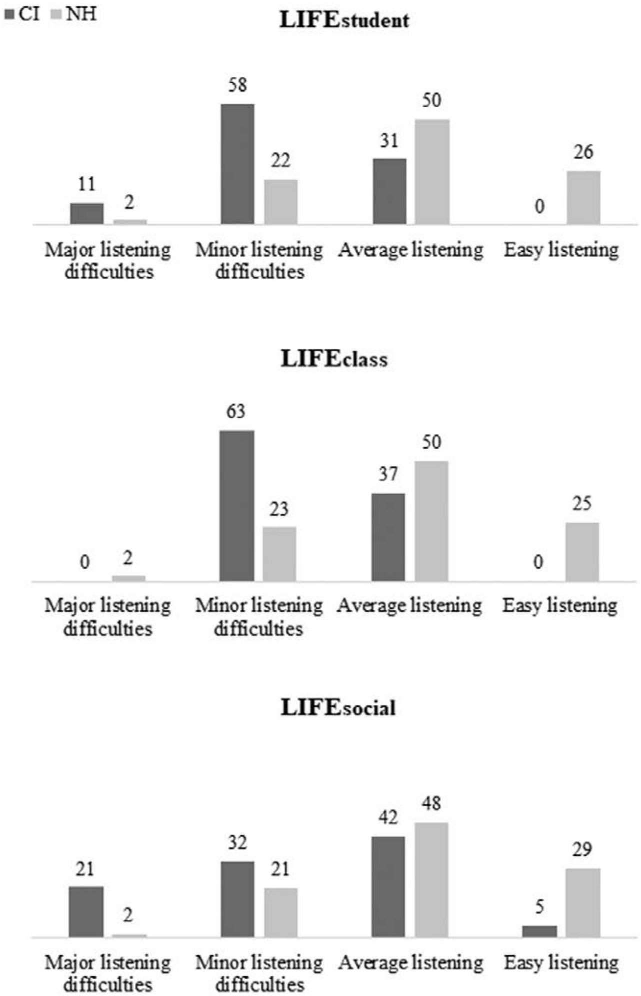

Fig. 4. Listening Profile of NH and CI participants. Percentages of participants who experienced "Major listening difficulties," "Minor listening difficulties," "Average listening," and "Easy listening." Percentages are shown for the $LIFE_{student}$ score and its subscores: $LIFE_{class}$ and $LIFE_{social}$. CI, cochlear implant; LIFE, Listening Inventory for Education; NH, normal hearing.

Comparisons Within Participants With a CI • Subgroup comparisons were carried out for (1) participants with a CI using HAT/no HAT and (2) participants with a CI in first/second cycle. The Fisher exact test showed no statistically significant differences between the subgroups, based on the number of participants having minor and major listening difficulties in each subgroup. Individual data plots of the subgroups are depicted in Figure A (Supplemental Digital Content 5, http://links.lww.com/EANDH/A618) and Figure B (Supplemental Digital Content 6, http://links.lww.com/EANDH/A619). Note that the 2 students (red dots) experiencing major listening difficulties were not using HAT.

LIFE2-NL for Teachers

The results of the LIFE2-NL for teachers related to how teachers perceive the listening challenges of children with a CI and their NH peers. First, the results were explored in a descriptive manner, followed by an inferential comparison between the CI group and NH group. Lastly, the self-advocacy strategies were described for the CI group only.

Descriptive Statistics • Teachers gave comparable scores to their students with a CI and their NH students for all questions of the teacher appraisal (see Figure 5 for median scores and interquartile scores of Q1 to Q15).

Comparisons Between Participants With a CI and Their NH Peers • The Fisher exact showed one significant difference between the NH participants and the participants with a CI—that is, for Q7 about their ability to stay on task. For that question more NH participants than participants with a CI received a low score (≤2) from their teacher ($p = 0.018$).

Self-advocacy Skills (Participants With a CI Only) • Five out of 8 self-advocacy strategies (Q2, Q4, Q5, Q7, Q8) were "often" or in "most opportunities" observed by the teacher in the CI group. Teachers indicated that participants with CIs only "sometimes" asked for immediate repetition during class (median score: 5, Interquartile (IQ) range = 2–10). Furthermore, teachers answered that participants with a CI "rarely" self-advocate for their needs in relation to multimedia (median score: 2, IQ range = 2–7). The use of a signal system to indicate something was not heard was "rarely used" or "not applicable" in the classroom (median score 0, IQ range = 0). Median scores and interquartile scores of all 8 self-advocacy questions are shown in Table D (Supplemental Digital Content 4, http://links.lww.com/EANDH/A616).

Related Comparisons • Results showed that for the teachers' appraisal, only 4 participants with a CI were listed in the category of "listening difficulties," whereas 14 participants with a CI experienced minor and major listening difficulties based on their self-report ($LIFE_{student}$).

Screening Instrument for Targeting Educational Risk

Comparisons Between Participants With a CI and Their NH Peers • Using the SIFTER tool, 18 teachers screened for educational risks on 5 content areas (academics, attention, communication, participation, and behavior) in their CI students and NH students. Within these groups (NH versus CI) median scores were comparable for all content areas (see Table 3). However, when the failure rate was analyzed (percentages of participants in the category "Pass" versus "Marginal and Fail"), a significant difference was found between the groups on one content area, namely on their behavior in class. Remarkably, significantly more NH participants scored within the fail and marginal category for behavior, compared with the participants with CIs ($p = 0.024$). Of the 18 participants with CIs, 4 obtained a marginal score for Communication.

Related Comparisons • Of the 4 participants obtaining a marginal score for Communication, only one was listed in the "listening difficulties" category in the teacher appraisal of the LIFE2-NL.

In Figure 6, results of all three questionnaires are represented next to each other, showing the percentages of students who were identified with (listening) difficulties. The graph gives a quick overview of the differences between groups (NH and CI) and the differences between the teacher and student questionnaires.

DISCUSSION

In this study, the listening difficulties of 19 early implanted children with CIs in secondary mainstream schools were documented. Although optimal auditory rehabilitation was provided

TABLE 2. Results of the LIFE2-NL for Students

LIFE Questions	Subject	Median	P25–P75	*p*	Estimated %	95% CI (Lower–Upper)
Q1 Teacher in front	NH	10	10–10			
	CI	7	7–10			
Q2 Teacher with back turned	NH	7	7–10	0.041*	4.4	2.0–9.4
	CI	5	5–7		17.3	5.0–45.4
Q3 Teacher talking while moving	NH	7	7–10	0.887	3.6	1.8–6.8
	CI	7	5–7		2.9	0.2–39.0
Q4 Students answering	NH	5	5–7	0.019*	7.0	4.4–11.1
	CI	5	2–7		25.1	9.7–51.0
Q5 Understanding instructions	NH	7	7–10	0.924	3.3	1.7–6.5
	CI	7	7–7		2.9	0.2–36.0
Q6 Other students making noise	NH	7	5–7	0.833	16.2	10.9–23.4
	CI	5	5–7		18.2	5.7–45.0
Q7 Noise outside classroom	NH	7	5–7	0.972	7.6	3.9–14.5
	CI	7	5–7		0	0.0–100
Q8 Multimedia	NH	7	7–10	0.002*	6.4	3.9–10.3
	CI	5	2–7		31.3	13.6–56.9
Q9 Listening in background noise	NH	7	7–10	0.665	4.6	2.5–8.1
	CI	5	5–7		7.0	1.1–34.1
Q10 Small + large group	NH	5	5–7	0.770	9.6	5.8–15.7
	CI	7	5–7		11.9	2.8–38.8
Q11 Small group learning	NH	7	7–10	0.001*	7.8	4.5–13.0
	CI	5	2–7		43.6	21.4–68.8
Q12 Listening during gym class	NH	7	7–10	0.003*	4.6	2.5–8.1
	CI	7	5–10		25.1	9.7–51
Q13 Listening in large room	NH	7	5–7	0.008*	14.4	10.4–19.4
	CI	5	0–7		31.3	13.6–56.9
Q14 Listening to others outside	NH	7	7–10	0.423	7.0	4.4–11.1
	CI	5	5–7		12.6	3.1–38.8
Q15 Listening during social times	NH	7	7–10	0.004*	4.9	2.7–8.5
	CI	5	5–7		25.1	9.7–51.0
LIFE student (Total)	NH	108	95–122	0.001*	23.0	17.3–29,8
	CI	86	77–98		75.1	48.8–90.5
LIFE class (Q1–Q10)	NH	72	64–82	0.002*	23.8	17.9–30.9
	CI	59	50–70		62.6	37.2–82.5
LIFE social (Q11–Q15)	NH	35	31–41	0.006*	23.1	17.9–29.3
	CI	29	19–29		56.3	32.2–77.7

Median scores and interquartile scores of the 15 questions of the LIFE2-NL, the $LIFE_{students}$ score, and its subscores: $LIFE_{class}$ and $LIFE_{social}$. In the adjacent columns the estimated risk of experiencing listening difficulties (score ≤ 2) are listed (estimated %).

**Significant differences between groups (NH vs. CI).*

CI, cochlear implant; LIFE, Listening Inventory for Education; LIFE2-NL, Listening Inventory for Secondary Education; NH, normal hearing.

due to early implantation, listening challenges may still occur in the classroom (e.g., due to excessive background noise and poor classroom acoustics).

In addition, a scoring grid was presented for the LIFE2-NL. The grid categorizes the total sum scores of the 15 listening situations into 4 categories. These categories indicate whether the score corresponds with "Easy listening," "Average listening," "Minor listening difficulties," or "Major listening difficulties." Results of the present study showed that participants with a CI were more likely to experience minor or major listening difficulties compared with their NH peers. The regression model estimated that 75% of the participants with a CI were at risk of experiencing listening difficulties, which was 3 times higher than their NH peers. These results confirm our initial hypothesis, that challenging listening conditions in school may adversely affect the speech understanding of children with CIs, even if they were implanted at a young age.

The 3 listening situations that had the highest chance of resulting in listening difficulties were (1) listening during group work, (2) listening to multimedia, and (3) listening in large classrooms. These results show that participants with a CI experience the most difficulties in situations where the speech signal is degraded—for instance, due to noise (background noises or chatting) or due to distortions (multimedia and reverberation).

It is known that understanding speech in noisy conditions is challenging for CI users (e.g., Zeng 2004; Caldwell & Nittrouer 2013). CI users mainly rely on the temporal envelope of the speech signal with a limited amount of spectral information and a lack of temporal fine structure. Due to this limited information, the speech signal is more difficult to distinguish from background noise (e.g., Friesen et al. 2001; Lorenzi et al. 2006; Hazrati & Loizou 2012).

Noise in unoccupied classrooms can originate from heating and ventilation systems, computers, projectors, or other equipment in the classroom (i.e., installation noise) or from external noise sources, such as traffic noise or noise from adjacent rooms and hallways. Levels of noise measured in unoccupied classrooms can range from 34.4 $dB_{(A)}$ to dB 65.9 $dB_{(A)}$

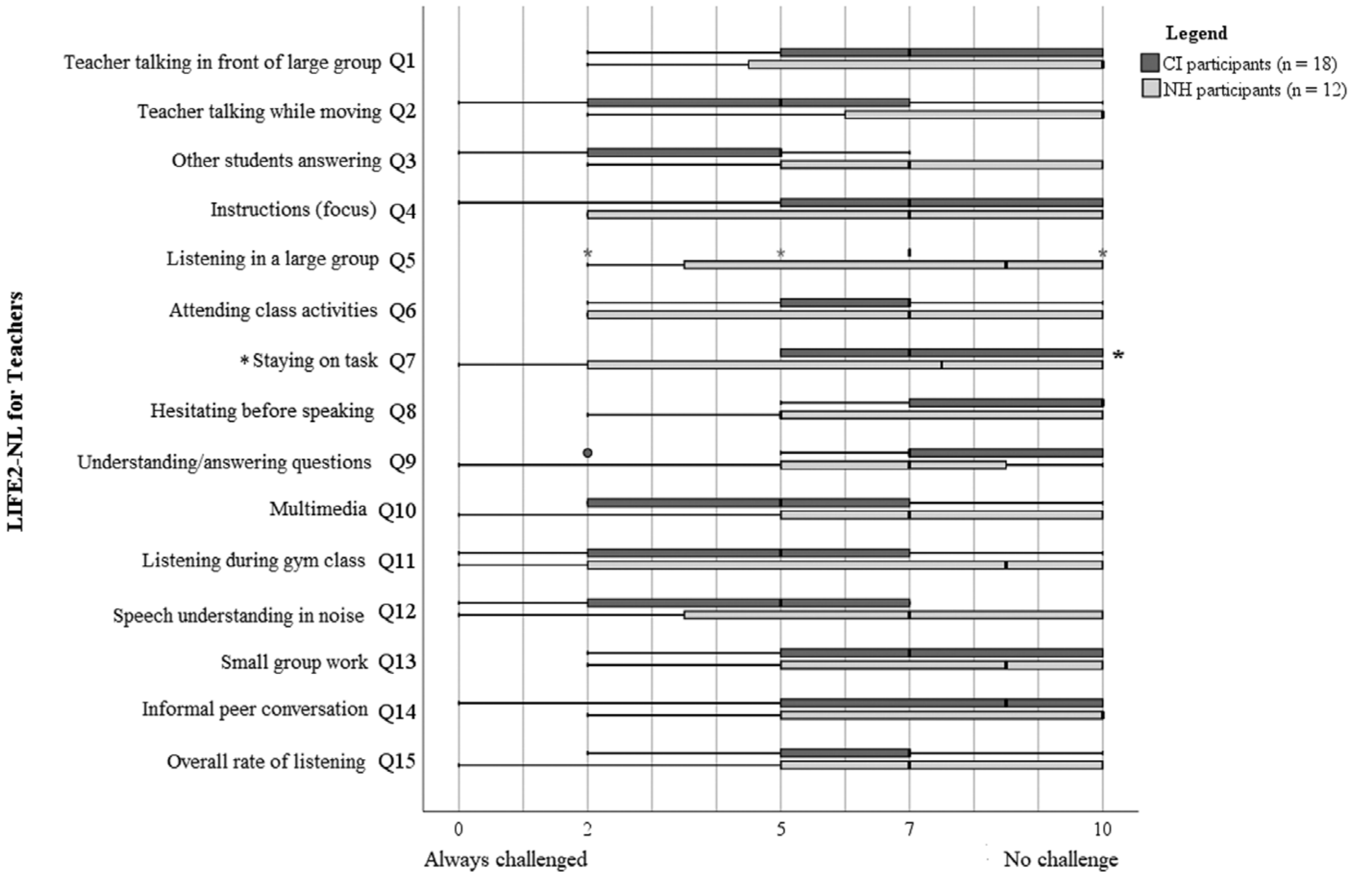

Fig. 5. LIFE2-NL for Teachers. The box plots represent the median scores and interquartile scores of the 15 LIFE2-NL questions. Significant differences between groups (NH vs. CI) are marked by an asterisk (*$p < 0.05$; **$p \leq 0.01$, ***$p \leq 0.001$). CI, cochlear implant; LIFE2-NL, Listening Inventory for Secondary Education; NH, normal hearing.

(Knecht et al. 2002). Conversely, in occupied classrooms, the noise can predominantly be attributed to student activity, causing background noise to increase by 10 $dB_{(A)}$ or more (Bradley & Sato 2008). It is therefore not surprising that in our study, students with a CI as well as NH students reported that the noises they hear in class mostly originate from other students (79%). Moreover, both participants with CIs and NH indicated being disturbed by other students making noise (from inside and outside the classroom). An SNR of 15 dB is recommended in classrooms for NH students (Nelson & Soli 2000). However, this ideal SNR is unfortunately not often achieved during teaching activities (Crandell & Smaldino 2000; Knecht et al. 2002), which may lead to listening difficulties and other psychoeducational problems (Crandell & Smaldino 2000; Klatte et al. 2013).

Speech understanding is not only affected by background noise; it is also influenced by the intensity and the quality of the speech signal (distortions). The mean intensity of the speech signal (teacher or student voices) in a quiet environment varies between 28 and 61 dB_{SPL} at 1 m distance (Boothroyd et al.

TABLE 3. Results of the SIFTER for Teachers

		Median	P25	P75	Pass (%)	Marginal	Fail	*p*
Academics	NH	11	9	15	73	18	9	0.603
	CI	11	10	12	88	6	6	
Attention	NH	12	7	15	73	27	0	0.646
	CI	11	10	13	83	17	0	
Communication	NH	11	9	15	73	18	9	0.599
	CI	11	10	12	78	22	0	
Participation	NH	11	8	14	73	18	9	0.108
	CI	11	10	12	94	6	0	
Behavior	NH	14	8	15	64	9	27	0.024*
	CI	14	13	15	94	6	0	

Median scores and interquartile scores of the four content areas of the SIFTER. In the adjacent columns, the percentages of participants scoring in the Pass, Marginal and Fail group are listed.
**Significant differences between groups (NH vs. CI).*
CI, cochlear implant; NH, normal hearing; SIFTER, Screening Instrument for Targeting Educational Risk

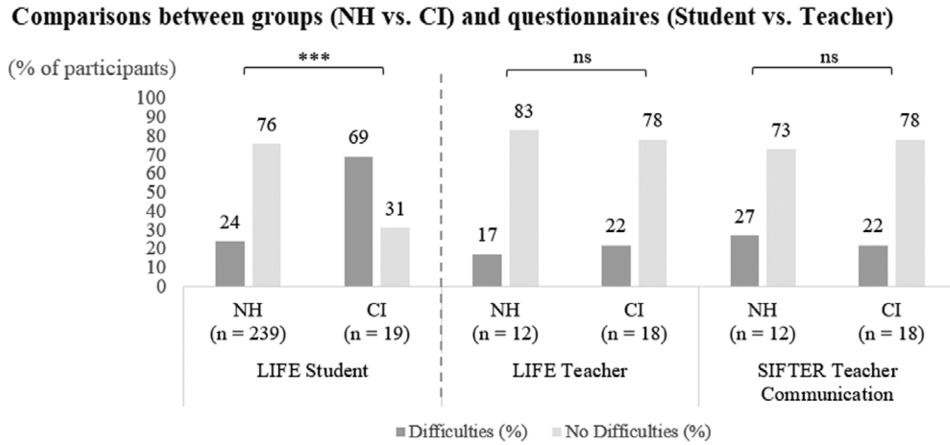

Fig. 6. Comparisons of questionnaires. Percentages of participants who were identified with difficulties by the three questionnaires (LIFE for students, LIFE for teachers, and SIFTER). Significant differences between groups (NH vs. CI) are marked by an asterisk (*$p < 0.05$; **$p \leq 0.01$, ***$p \leq 0.001$). CI, cochlear implant; LIFE, Listening Inventory for Education; NH, normal hearing; SIFTER, Screening Instrument for Targeting Educational Risk.

1994). If the distance from the speaker increases, the intensity of the direct signal decreases with 6 dB for every doubling of distance (i.e., inverse square law). If the listener is placed beyond a critical distance, (s)he will not only receive the original signal (direct signal) but also the reflections of the signal caused by reverberation in the room. Rooms with high reverberation times (e.g., >0.6 s) will produce more late reflections, which can distort the temporal and spectral cues of the speech signal (see review Nabelek 1993). Reverberation times longer than 0.6 s are fairly common in typical Belgian classrooms. Vermeir and Degeetere (Reference Note 1) assessed the classroom acoustics of 50 randomly selected classrooms in nursery, elementary, and secondary schools and determined a mean reverberation time of 0.86 s (range = 0.3–1.7 s). Furthermore, research in young adolescents with a CI showed that speech understanding significantly decreased in reverberant conditions and that the deficit was greater when noise and reverberation were combined (Neuman et al. 2012).

Almost all of the participants with a CI in this study (85%) were positioned in the front row. Unfortunately, a seat in the front row position does not ensure a position within the critical distance of the direct speech signal. Nevertheless, participants with a CI responded that this position was a good position for understanding the teachers' instructions. In the situations where the distance increased—for example, when other students answered in a discussion from a position across the classroom or when they had to follow instructions in large-sized classrooms—participants with CIs indicated they sometimes had problems with speech understanding. This finding aligns with studies showing the effect of distance and classroom acoustics on the speech perception of CI users (e.g., Hazrati & Loizou 2012). Another finding from this study that needs further attention is the difficulty that was reported while listening to multimedia. When the speech signal is played from multimedia or speakers, the quality of the signal relies on the frequency representation of the loudspeakers, which can lead to spectral distortions. These distortions, combined with the reduced spectral information that a CI provides, can result in substantial listening difficulties (Duke et al. 2016).

When the speech signal is poor (low SNR or distortions) children with a CI will try to rely on their individual compensation strategies (e.g., speechreading) or their HAT, such as Remote Microphone (RM) systems.

With regard to speechreading, 95% of the participants with a CI reported they would turn around to face the student who is responding, and 53% indicated they had to look at the lips of the teacher if they did not understand what was said—compared with 45% and 2% of the NH peers. This concurs with the finding that participants with a CI found it more difficult than NH peers to understand teachers who had their back turned. These findings suggest that (1) the current group of participants with a CI rely more on visual cues than their NH peers and/or that (2) they benefit from the directional microphones of their CI when facing the person who is speaking.

Visual cues congruent to the auditory signal (audiovisual input) can enhance speech perception in both NH listeners and listeners with hearing loss (Erber 1971; Lachs et al. 2001; Bergeson et al. 2003). However, the benefit of visual cues depends on the available auditory information and hearing status of the listener (Bayard et al. 2014). Therefore, it is conceivable that CI users rely more on visual cues compared with NH listeners, particularly in difficult listening situations. Listening to multimedia is often an auditory-only condition, which is why participants with a CI—in addition to the distorted multimedia output—may experience difficulties with understanding speech from multimedia devices.

The directional microphones of CIs can improve the SNR by increasing the sensitivity for signals coming from the front and by attenuating noise from nonfrontal sources (Chung et al. 2006). The benefit of directional microphones in school environments is estimated at around 3 dB (Ricketts et al. 2007; Ching et al. 2009). The benefit is, however, dependent on several factors, such as the distance to the talker and the reverberation in the room (Ricketts 2000); therefore, it is difficult to extrapolate these findings to real-life listening situations.

HAT can be used to optimize speech understanding in classrooms. HAT increases the SNR while overcoming the detrimental effects of distance, background noise, and reverberation (Zanin & Rance 2016; De Ceulaer et al. 2017). Most HAT devices (e.g., RM) can be connected to multimedia devices, which will directly stream sound to the CI, thus bypassing possible distortions of the multimedia output. In the present study, only 42% of the participants with a CI used an RM in the classroom. However, an RM can significantly improve speech understanding in the classroom (Rekkedal 2012; Zanin & Rance 2016). Zanin and Rance (2016) reported results from students with HAT and CIs who filled out the LIFE questionnaires before and after using an RM in class and found that the mean LIFE score improved approximately 20% (71% with versus 50% without RM). Conversely, in the present study, no significant differences were found between the groups with and without RM. In contrast with Zanin and Rance, we did not administer the questionnaire to the same student twice (with and without RM), and our 2 groups were fairly small. Further research is needed on larger sample sizes to ascertain the individual effect of RM. In this study, it would be interesting to investigate if RM would have a beneficial effect upon our 2 participants with CIs who experienced major listening difficulties and did not use RM. Reasons for not using RM were mostly related to psychosocial factors—such as social stigmatization, low self-esteem, and fear of being identified as the only abnormal student in class (Rekkedal 2012). These reasons could explain why none of our participants with CIs used their RM device during social interactions. In social listening situations, SNRs may decrease due to exhaustive background noise; therefore, RM could have a beneficial effect on the speech understanding. These interactions are considered to be stimulating moments for incidental learning, which are important for learning and developing narrative skills, reading skills, interactive skills, and social-emotional skills (e.g., Vermeulen et al. 2007). Interactive and social-emotional skills are founded upon emotion understanding and pragmatic abilities, which are both less developed in children with CIs than in NH peers (Terwogt & Rieffe 2004; Most et al. 2010; Wiefferink et al. 2013).

In summary, we characterized the origin of the 3 most common listening difficulties in participants with a CI and discussed some of their coping strategies (use of HAT and visual cues). The listening difficulties were assigned to low SNRs, distortions (multimedia, reverberation), a lack of visual support, distance, and directivity effects of the microphones. In Table 4, a list of 7 listening difficulties, that caused significantly more difficulties in participants with CIs than in their NH peers, were listed. Based on our discussion, we listed the (acoustical) characterization of every listening situation and suggested an appropriate recommendation to minimize the difficulties in classroom. The listening difficulties were arranged by their estimated percentage of occurrence in participants with a CI. This list could be used in schools to increase awareness for difficult listening situations among teachers.

Furthermore, 18 teachers filled out the teacher appraisal of the LIFE2-NL and the SIFTER. Due to the limited data, no statistical analyses were possible to compare the teacher appraisal to the student appraisal and to the SIFTER. However, we noted that fewer teachers indicated that their students with CIs experienced listening difficulties, compared with when students themselves filled out the questionnaire. This may imply that teachers underestimate the listening difficulties of their students with a CI, but further research on a larger sample is necessary. Furthermore, the SIFTER and the $LIFE_{teacher}$ seemed to expose different difficulties, as different students were identified as having listening difficulties (LIFE) to those having communication difficulties (SIFTER). Perhaps the questions of the SIFTER communication section are more related to the language abilities of the child, whereas the LIFE explores the listening abilities in specific situations at school.

Contrary to Damen et al. (2006), our study did not show lower scores on the content area of communication for the participants with a CI, when compared with their NH peers. Our CI group was implanted before the age of 2 years (mean age of implantation = 1 year 1 month; SD = 3 months), which is remarkably lower than the upper limit of 9.7 years reported by Damen et al. (mean age of implantation was 3.7 years). Early cochlear implantation is correlated positively with speech perception outcomes and could therefore minimize (basic) communicational risks (Govaerts et al. 2002; Sharma et al. 2002) and risks for delay in language development (e.g., Coene & Govaerts 2014). However, when communicational demands in secondary schools become more complex, listening difficulties may arise and are therefore better examined with a more sensitive and in-depth questionnaire such as the LIFE2-NL/LIFE-R.

A final notable finding in the present study is that early implanted children seem to surpass their NH peers in some

TABLE 4. List of Most Common Listening Difficulties Among Students With a CI

Listening Difficulty	Risk of Occurrence	(Acoustical) Characterization	Recommendation
Listening during group work	44%	Low SNR	Complete group work in a separate room Use HAT
Listening to multimedia	31%	Distortions in signal and no visual feedback	Use subtitles Use direct streaming (HAT)
Listening in large class rooms	31%	High reverberation	Decrease distance to listener Use HAT
Students answer during class discussion	25%	Low SNR, no visual feedback, distance to speaker, directivity effects	Repeat what student has said Rearrange desks Use HAT + pass-around mic
Listening in gym	25%	High reverberation	Minimize distance for oral instructions Use HAT
Listening during social times	25%	Low SNR	Use HAT
Listening to teacher with back turned	17%	No visual feedback, directivity effects, low SNR	Use HAT

The listening difficulties were arranged by their estimated percentage of occurrence in participants with a CI. The (acoustical) characterization of every listening situation was listed together with a suggested recommendation to minimize these difficulties.
CI, cochlear implant; HAT, hearing assistive technology; SNR, signal to noise ratio.

aspects of the questionnaires. The teachers gave higher scores to children with a CI for their behavior in class (SIFTER) and their ability to stay on tasks (LIFE-R). It is unclear if this finding is related to the small sample size or possible selection bias (see below for limitations) or if it is a result of the therapeutic interventions they have received so far. Perhaps children with a CI demonstrate better school behaviors because they were trained in active learning attitudes from the beginning of their rehabilitation process with their CIs. These attitudes may even be a contributing factor to their attainment in mainstream schools and should be further explored when school results are examined in this group.

Finally, a number of potential limitations need to be considered. In this study, we were able to compare each individual participant with a CI to his or her classmates, who functioned as an interesting, diverse, and large control group. However, because we did not check the participants' hearing objectively at the time of the questionnaire administration (only by report/based on screenings), there might be an overestimation of the listening difficulties of NH participants. Still, significant differences were found between NH participants and participants with a CI, which further emphasizes the need to be attentive for possible hearing problems of children with a CI in school. Additional follow-up studies are planned by our research group to further investigate the listening difficulties of participants with a CI, with more objective methods to measure their everyday speech understanding. These tests include both noise and reverberation to mimic typical listening situations at school (see Neuman et al. 2012). Although we were able to validate our regression model with a bias-accelerated bootstrap validation, we acknowledge the limitations related to the small sample size of the CI users and the heterogeneity within this group. Further research is necessary to validate the "Listening profile" on a larger number of CI users, and individual follow-up is advised concerning their experienced difficulties in school. Furthermore, the small sample size prevented us from performing comprehensive analyses of the $LIFE_{teacher}$, the SIFTER, and the CI subgroups. Further data collection is required to investigate if teachers are able to estimate the listening difficulties of CI users accurately and to document the individual beneficial effects of RM in class.

CONCLUSION

In this study, we identified the listening difficulties of early implanted children with a CI in mainstream secondary education. Despite their early access to auditory rehabilitation, they still experience more listening difficulties than their NH peers in class. It was estimated that 75% of the participants with a CI were at risk of experiencing listening difficulties at school. For 7 out of 15 listening situations, the chances of experiencing listening difficulties were significantly higher in participants with a CI, when compared with NH participants. The origin of the difficulties was characterized by low SNRs, distortions (multimedia, reverberation), distance, a lack of visual support, and the directivity effect of the microphones. Earlier, we provided a list with the most common listening difficulties among students with a CI, together with a characterization of the difficulty. An appropriate recommendation (such as the use of HAT and visual cues) was suggested for each difficulty to raise awareness among teachers and to minimize the difficulties in classroom.

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