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ORIGINAL ARTICLE

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Occupational performance of cochlear implant users: a comparative study with other hearing-impaired and normal-hearing individuals

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ABSTRACT

Objective and design: This cross-sectional study aimed to compare occupational performance of cochlear implant (CI) users to that of adults with hearing impairment without CI and those with normal hearing (NH). We used the Amsterdam Checklist for Hearing and Work to assess job characteristics, hearing activities, need for recovery and other outcomes.

Study sample: We included 204 adults: 98 CI users (mean age 51), 52 participants with hearing impairment, without CI (HI group, mean age 49) and 54 participants with NH (NH group, mean age 46).

Results: Job characteristics were similar between the groups, but the CI and HI groups were significantly more likely to report (effortful) communication in noise compared to the NH group. Need for recovery was significantly higher in the HI than in the NH group, but the CI and NH groups showed no significant difference. The CI group needed less guidance in managing their hearing loss in the workplace than the HI group did.

Conclusions: The relatively favourable outcomes for CI users in need for recovery and reduced need for guidance at work may be due to the extensive training and counselling they received as part of their rehabilitation program.

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Cochlear implant; hearing; work; employment; occupation; need for recovery

Introduction

Approximately 5% of the population worldwide has disabling hearing loss. It is estimated that this prevalence will increase to 10% by 2050 (World Health Organisation 2024). In the Netherlands, debilitating hearing loss ($\geq$ 35 dB in the better ear) occurs in 13 percent of the population aged 40 years and older (van der Meijden et al. 2020). Hearing loss generally negatively affects physical and mental health, quality of life (Lailach et al. 2024), education and employment (Kramer, Kapteyn, and Houtgast 2006; Lailach et al. 2024; Olsson et al. 2022; World Health Organisation 2024). Several studies indicated that people with hearing loss are less likely to have a high income (Jung and Bhattacharyya 2012) and paid work for more than 12 hours per week, compared to people with normal hearing (NH) (Stam et al. 2013). Nachtegaal et al. (2009) showed that poorer hearing was significantly associated with a higher need for recovery. Need for recovery after work is a short-term effect of work and is seen as an indicator of fatigue. It manifests itself as a transient feeling of overload, irritation, a desire to be left alone, a lack of energy, and a decline in performance (van Veldhoven and Broersen 2003). Incomplete recovery from work can lead to psychosomatic health problems (de Croon, Sluiter, and Frings-Dresen 2003), sick-leave (Pierre et al. 2012; Svinndal et al. 2018) and ultimately in withdrawal from work and early retirement (Kramer, Kapteyn, and Houtgast 2006; Nachtegaal, Festen, and Kramer 2012; Nachtegaal et al. 2009).

Individuals with severe hearing loss can be supported with a cochlear implant (CI). Although CIs generally improve speech understanding in relatively quiet listening situations, participating in groups (educational settings, work meetings, social gatherings) remains difficult. Also, increased fatigue and stress levels are reported by CI users (Hughes et al. 2018). However, there is limited data available on the experiences of CI users in occupational settings (Lailach et al. 2024). Nijmeijer et al. (2021) and Kumar and Chinnaraj (2023) conducted review studies on the effectiveness of a CI on participation in work. Inconsistent findings were reported, which was mostly due to heterogeneous methodologies used to study the topic. For example, quantitative and qualitative cross sectional studies were performed, as well as prospective and retrospective studies. Some of the questionnaires were open-ended, unspecified, or not validated. The majority of the included studies assessed the change in employment status after CI implantation relative to pre-implantation (Clinkard et al. 2015; Fazel and Gray 2007; Lailach et al. 2024; Nijmeijer et al. 2021). Implantation can increase employment and result in

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higher levels of independence, job satisfaction, income, less experienced listening effort and reduced listening-related fatigue (Clinkard et al. 2015; Fazel and Gray 2007; Hornsby et al. 2024; Hughes et al. 2018; Olsson et al. 2022). Lailach et al. (2024), however, reported that subjective work ability, like sick-leave in the last year, did not significantly improve after CI treatment. Illg et al. (2017) examined the long-term occupational outcomes in pre-lingually implanted CI users and compared these to the general population in Germany. The occupational levels achieved by CI users were poorer than those of the average German and worldwide population (Illg et al. 2017; Kumar and Chinnaraj 2023).

As occupational performance is a multifaceted concept, it is important to examine the characteristics of the job (e.g. the number of working hours), features of the workplace environment, and main activities or tasks required for the job. These can influence outcome variables like the need for recovery after work, sick-leave and reported listening effort in the workplace. To the best of our knowledge, there are no studies that directly compared occupational performance of CI users to that of individuals with hearing loss (with or without hearing aids) and with individuals with NH. That was the aim of the current study. We specifically aimed to compare the occupational characteristics of CI users with individuals across a broad range of hearing loss severity (HI), as well as those with NH. Therefore, hearing levels were not matched between the CI group and the HI group.

To address the aim, we used the Amsterdam Checklist for Hearing & Work (Kramer, Kapteyn, and Houtgast 2006). We expected that CI users are disadvantaged in occupational performance compared to the HI group, as CI users generally have a more severe hearing loss than the general range of individuals with hearing loss without CI. Based on the above-described research in listeners with hearing loss, we expected poorer work-related outcomes in individuals with hearing loss compared to the NH group. More specifically, we expected that both the CI and HI group would work fewer days or distribute their working hours over more days in the week than individuals with NH. In addition, we expected that individuals in both the CI and HI group would less often have roles for which communication is central (e.g. supervisory positions) compared to their NH colleagues. In addition, we expected that participants of the CI and HI groups would report higher levels of listening effort, environmental noise (Kramer, Kapteyn, and Houtgast 2006), and reverberation compared to the NH group. Finally, we expected both groups with hearing loss to have higher levels of sick-leave compared to those with NH (Nachtegaal, Festen, and Kramer 2012). We also expected that the CI and HI group, compared to the NH group, would report higher levels of need for recovery after work, and poorer relationships with colleagues.

Methods

This cross sectional comparative study aimed to compare the outcomes of the Amsterdam Checklist for Hearing and Work between CI users and two reference groups (HI and NH). All three groups completed the online questionnaire using the software Castor EDC (2023).

Study sample

Participants of the CI and HI groups were recruited among patients of Amsterdam University Medical Centre (Amsterdam UMC) and Leiden University Medical Centre (LUMC). The NH group was recruited by asking participants in the CI and HI groups to ask their relatives, colleagues or partners with NH to complete the questionnaire. In addition, participants were recruited through 1) posting information about the project on relevant websites and/or social media, and 2) distributing information leaflets in the waiting rooms of the department of Ear-Nose-Throat surgery of both medical centres. Participants were eligible to join the study if they were between 18 and 67 years old. In the Netherlands, the retirement age is 67 years, but some professions allow for earlier retirement. Therefore, the age of 67 years was selected as the upper limit for inclusion. We selected participants with paid employment, voluntary work and/or being enrolled in an educational program. Participants had to be proficient in Dutch and had to have normal or corrected-to-normal eyesight. In addition, the onset of profound hearing loss or deafness in the CI users had to be post-lingual (>7 years of age). Finally, they had to have received their CI after the age of 12 years and at least 1 year before participating in the study. An exclusion criterion for all subgroups was intellectual disability, as participants had to complete the questionnaires themselves. These criteria were checked in the patient records by the main hearing care provider before recruiting potential participants. There were no inclusion criteria regarding the degree of hearing loss or hearing aid (HA) use for the HI group. CI and HI group participants were not matched in severity of hearing loss.

In total, 343 patients of Amsterdam UMC and LUMC were invited to participate in our study (i.e. 222 CI users and 121 individuals with hearing loss without CI). Individuals were considered non-respondents if the informed consent form was not returned and/or when none of the survey questions was answered. Age and gender differences between the non-respondents and respondents were examined, using an independent samples t-test and a Pearson Chi-Square test, respectively. We used the initial date of our recruitment as a reference point for age: 01-12-2022 (recruitment lasted from 01-12-2022 to 27-02-2024). The CI respondents were significantly older than the CI non-respondents ($t\ (216.321) = -2.581$; $p=.011$). There were no significant age and gender differences between respondents and non-respondents for the HI group (see Supplementary Material Table S1).

Data of participants were included in the analyses if the survey was fully completed and for the NH group if the Digits-In-Noise (DIN) test (Smits, Theo Goverts, and Festen 2013) was completed too. This resulted in the exclusion of $n = 7$ participants in the CI group, $n = 4$ in the HI group and $n = 24$ in the NH group.

The final sample included 204 participants: 98 in the CI group, 52 in the HI group, of which 41 were HA users and 54 in the NH group. Out of these participants, 77 (79%) CI users, 39 HI (75%) and 39 NH (72%) participants indicated that they worked predominantly "on site" (e.g. office or hospital) versus "at home".

The HI group consisted of individuals with different types of hearing loss. For one person this information was missing. Twenty-two (43%) had sensorineural hearing loss, five (10%) had conductive loss and eighteen (35%) had mixed hearing loss. For six participants (12%), one or both ears had severe to profound hearing loss, making it impossible to determine bone conduction thresholds.

Brands used by CI users were Advanced Bionics LCC, Valencia, CA, United States ($n = 67$), Cochlear Corporation, Sydney, Australia ($n = 27$), MED-EL Worldwide Headquarters, Innsbrück, Austria ($n = 3$) or Oticon A/S, Smørum, Denmark ($n = 1$).

Ethical considerations

The Medical Ethical Committees of Amsterdam UMC, location VUmc and the Leiden, The Hague and Delft METC LDD, with project numbers respectively SQC2022-008 and N22.012, confirmed that the study did not fall under the scope of the Dutch Medical Research Involving Human Subjects Act (WMO). Hence, the study was exempt from review by the Medical Ethics Review Committee. Participants signed (digital) informed consent (Castor Electronic Data Capture, 2023, New York, United States).

Procedure

The Amsterdam Checklist for Hearing and Work (Kramer, Kapteyn, and Houtgast 2006) covers demographic characteristics and includes three sections. Section 1 "Job Characteristics" includes current work situation (paid job, voluntary work, or education), type of contract (temporary versus permanent), supervisory position (no versus yes), working hours and days, main activities or tasks required for the job (e.g. telephone conversations, meeting in groups, administrative work, medical care), further referred to as "tasks at work" and workplace environment.

Section 2 "Hearing activities" focuses on the occurrence and importance of occupational hearing activities. Five different hearing activities are distinguished: detection of sounds; speech communication in quiet; speech communication in noise; distinguishing between sounds; and localisation of sounds (Kramer, Kapteyn, and Houtgast 2006). Participants were asked to indicate how frequently they encountered each activity, using the following response categories: almost never (0), sometimes (1), often (2), almost always (3). An example item is: "How often do you need to listen to speech in a noisy environment?". For each hearing activity, participants also indicated how much effort they needed to perform it, using the response categories: no effort (0), a little effort (1), much effort (2), very much effort (3), with higher scores indicating more effort (Kramer, Kapteyn, and Houtgast 2006). An example item is: "How much effort and concentration do you need during listening to speech in a noisy environment?" The mean of the five activities was calculated and is further referred to as "effort in hearing". This section also included questions on self-perceived environmental noise and on self-perceived reverberation. The exact wording of the questions was "Is there environmental noise in the workplace?" and "Is there reverberation in the workplace?" Response categories were none [0], a little [1], much [2] and very much [3]. The categorical variables "effort in hearing", "environmental noise" and "reverberation" were transformed into continuous variables.

Section 3 "Working conditions and sick-leave" deals with general working conditions and sick-leave. Three subscales of the Dutch questionnaire on Perception and Judgement of Work were included: Need for recovery after work (dimension Stress), Relationship with colleagues (dimension Social-organisational) and Participation (dimension Job control) (van Veldhoven, Broersen, and Fortuin 2002; van Veldhoven, van der Laken, and Dijkstra 2015). These latter two dimensions might be affected by communication difficulties associated with hearing loss.

1. "Need for recovery" (11 items), assessed: (1) fatigue immediately after work, (2) fatigue during the evening and (3) social consequences of fatigue (van Veldhoven, van der Laken, and Dijkstra 2015). The total score was transformed into a percentage, with higher percentages indicating a higher need for recovery.
2. "Relationship with colleagues" (9 items) assessed atmosphere, support and conflict (van Veldhoven, van der Laken, and Dijkstra 2015). Scores were averaged, with a lower score indicating a more positive relationship with colleagues.
3. "Participation" (8 items) assessed participation and approachability of supervisors (van Veldhoven, van der Laken, and Dijkstra 2015). Scores were averaged.

The need for guidance at work was measured by one item: "Do you need guidance in managing your hearing loss in the workplace?" with response categories no, yes. Finally, Section 3 included sick-leave (no, yes), number of sick-leave days during the last 12 months and reason for sick-leave. The classification of the reasons for sick-leave and example items of the three subscales of this section, are included as Supplementary Material.

In addition, for both the CI and HI group, we obtained data from the clinical electronic patient records. We extracted data on HA or CI brand, duration of CI use, and data on aetiology and degree of hearing loss:

1. Aided consonant-vowel-consonant (CVC) speech audiometry data in quiet at a presentation level of 65 dB SPL.
2. Aided speech intelligibility in noise, including the diagnostic DIN test (Amsterdam UMC) and the CVC phoneme score obtained in stationary noise at a signal-to-noise ratio (SNR) of +5 dB (LUMC). The CVC score was obtained using 3 word lists of 10 words each (Bosman 1989). In this test, the sound level at which intelligibility reaches its maximum is assessed for each ear separately. This reflects the ability to distinguish one speech sound from another and should represent the outcome with HAs. We report the highest unaided CVC phoneme score (in percent correct) with headphones. The DIN test consists of digit triplets in long-term speech-spectrum noise and measures the speech reception threshold for 50% correct perception of the triplets (Smits, Theo Goverts, and Festen 2013).
3. Unaided pure-tone hearing thresholds, for air-conduction at the octave frequencies between 500–8000 Hz and for bone conduction between 500–3000 Hz.

There were many missing data for aided speech in noise for the HI group. For the CI group, unaided pure-tone hearing thresholds were incomplete due to the severity of hearing loss.

Data on diagnostical tests were obtained from at least 6 months after CI implantation and up to a maximum of six months after the checklist was completed. The most recent data on speech intelligibility in quiet were 1 year before inclusion in the study ($n = 98$, 25th–75th percentile: 0–4 years; range 0–12 years) for the CI group and less than 1 year before inclusion ($n = 23$, median: 0, 25th–75th percentile: 0–1 year; range 0–4 years) for the HI group.

For the NH group, we used a self-administered web-based DIN test to check hearing acuity of each participant (Smits, Theo Goverts, and Festen 2013). Participants completed this test after completion of the survey.

Statistical analysis

We examined differences in demographic characteristics between all three groups using One-way ANOVA and Pearson Chi-Square tests. We used an independent samples t-test or a Fischer's exact test to test for differences between the CI and HI group for variables that were not acquired for the NH group (see Supplementary Material Table S2). Descriptive statistics were calculated for the variable "tasks at work" and for several "workplace environment" variables. Not all variables were statistically tested, due to the relatively small numbers in most categories.

When testing the effect of hearing status (CI, HI and NH) on all work performance outcomes (see Tables 1–3), we checked whether age had to be incorporated as a confounding covariate, because age differed slightly, but significantly between groups (see Supplementary Material Table S2). This was done by the following procedures:

1. The linearity of the relation between age and each outcome was assessed by using ANCOVA, logistic regression or ordinal regression, depending on the distribution of the outcome measure.
2. The effect off age was tested for significance using Pearson or Spearman correlations, logistic regression, or ordinal regression, again depending on the distribution of the outcome measure.
3. The effect modification by age was assessed by testing the interaction between group and age (or age-group for non-linear relationships) for all outcome measures. If age was an effect modifier, we stratified the results based on two age subgroups: a) participants 18 to 50 years ($n = 102$), b) participants 51 to 66 years ($n = 102$).
4. Lastly, in case of a significant association between age and the outcome, but in the absence of effect modification, we tested whether age was a confounder. If this was the case, a corrected model was presented (ANCOVA or logistic/ordinal Regression).

If age was neither an effect modifier nor a confounder, we presented the results of the initial model testing the effects of group (without including age) using a One-way-ANOVA, Kruskall–Wallis test, logistic regression, or ordinal regression, depending on the distribution of the outcome measures. Post-hoc tests were performed within ordinal regression analyses. Post-hoc tests after ANCOVA or logistic regression, were performed with a Bonferroni correction.

A corrected model was presented for hours of work per week, workdays per week, and type of contract. Stratified results were presented for communication in quiet. For other outcomes, all initial models were presented.

The HI group comprised participants with and without HAs. Therefore, we conducted a sensitivity analysis, including HA users only. Each analysis was repeated for the subgroup of HA users ($n = 41$).

The significance level was set at alpha = 0.05. Analyses were performed using SPSS version 28 (IBM SPSS Statistics).

Results

Demographic characteristics

The mean ages of the participants in the CI, HI and NH groups were 51, 49 and 46 years, respectively (see Supplementary Material Table S2).

A One-way ANOVA revealed a difference in mean age between the groups ($F(2,201) = 3.67$, $p = .027$). Post-hoc analyses indicated that the mean age was significantly higher for the CI group (51 years) compared to the NH group (46 years) ($p = .022$, 95% C.I. = [0.57–9.92]). A One-way ANOVA (2 groups) also showed that the CI group had a longer duration of hearing loss compared to the HI group ($F(1,147) = 41.23$, $p < .001$). In addition, participants in the CI group more frequently had attended education for the Deaf and Hard of Hearing (DHH) ($p < .001$) and used the direct-streaming functionality of their CI more often than the HI group with their HAs (2-sided Fischer's exact test, $p = .005$). The HI group more often used headphones than the CI group (2-sided a Fischer's Exact Test, $p = .004$). There were no significant differences between the CI, HI and NH groups in gender distribution ($p = .873$), living situation ($p = .182$) and level of education ($p = .231$).

Speech intelligibility: CI users versus HA users

We calculated the mean phoneme scores for the CI group, but present median scores for the HI group, as their scores were not normally distributed. CI users had a mean phoneme score of 87% in quiet at 65 dB SPL. This was measured unilaterally in case of one CI ($n = 95$) and bilaterally in case of 2 CIs ($n = 3$). However, 48 CI users had a HA on the contralateral ear. For them, speech intelligibility in quiet at 65 dB SPL was 88% phonemes correct (SD 10, range 53–100%) ($n = 26$) with their CI fitting in combination with their HA contralateral). In noise, CI users ($n = 69$) had a mean speech intelligibility of 68% CVC phoneme score at 65 dB SPL (SNR +5dB) or a diagnostical DIN score of −2 dB SNR ($n = 16$). Both mean scores reflect great difficulty to understand speech in noise in daily life (Smits, Theo Goverts, and Festen 2013). Participants with HA had a median of 97% phonemes correct in quiet at 65 dB SPL, which was mostly measured with the daily life fitting ($n = 21$), namely either with bilaterally fitted HAs ($n = 16$) or an unilaterally fitted HA ($n = 5$).

Outcomes Amsterdam Checklist for hearing and work

Section 1: job characteristics

A chi-square test indicated that there were no significant differences between the groups concerning their current work situation (paid job, voluntary work or education). There were no

Table 1. Work and educational characteristics.

	CI (n = 98)	HI (n = 52)	NH (n = 54)	*p* value
Current work situation				
Paid job, n (%)	91 (92.9%)	47 (90.4%)	53 (98.1%)	.183[a]
Voluntary work, n (%)	5 (5.1%)	5 (9.6%)	0 (0.0%)	
Education, n (%)	2 (2.0%)	0 (0.0%)	1 (1.9%)	
Type of contract, (n temporary/ n permanent)	16/82	14/38	10/44	.243[c]
Supervisory position, (n no/ n yes)	82/16	38/14	36/18	.053[b]
Hours of work per week, mean (SD; range)	30.4 (11.2; 2–65)	30.5 (10.9; 1–50)	33.1 (7.7; 15–60)	.483[d]
Workdays per week, mean (SD; range)	4.0 (1.0; 1–6)	4.2 (1.3; 1–7)	4.4 (0.8; 2–6)	.196[d]

[a]Pearson Chi-Square test, [b]Wald test, [c]Wald test, including age as covariate, [d]ANCOVA, including age as covariate.
Significance levels are presented for the group effects.

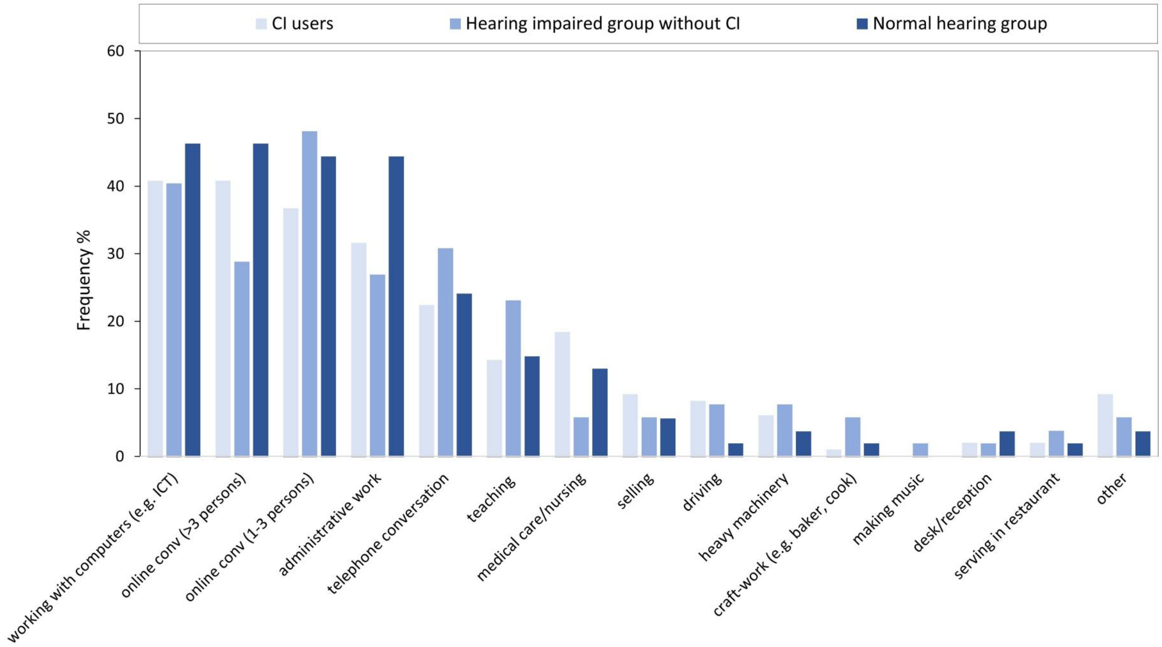


Figure 1. Tasks at work.

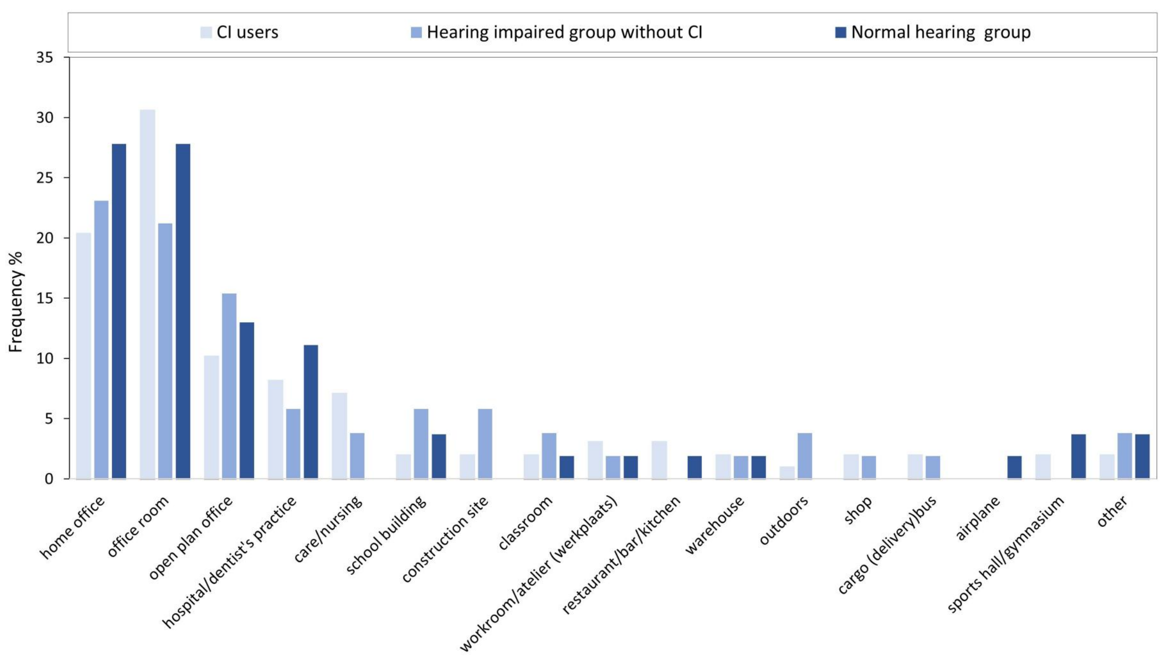


Figure 2. Workplace environment.

differences between groups for type of contract (temporary versus permanent), or number of working hours per week either. Taking into account the effect of age, the number of working days also did not differ between the groups. Also, there were no group effects on supervisory position. The results are presented in Table 1.

The distribution of work tasks per group is shown in Figure 1. No significant differences were found in tasks at work, indicating that the groups had to perform comparable tasks during their jobs.

The distribution of workplace environments per group is shown in Figure 2. The majority of the participants reported to work in a home office, office room, or in an open plan office. Most of the remaining categories were selected less frequently, which prohibited statistical testing of differences between the groups.

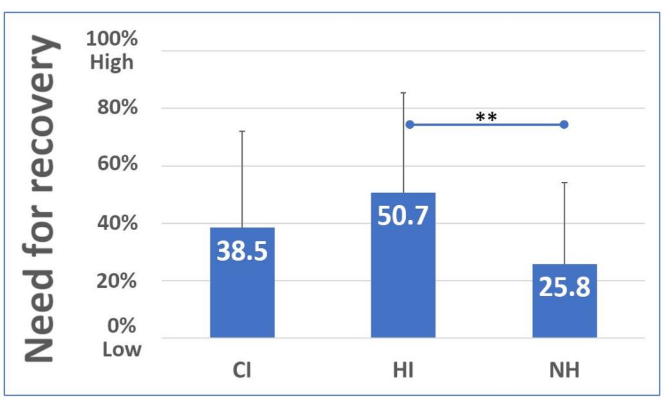
Section 2: hearing activities

The groups differed significantly in their self-perceived hearing activities. Ordinal regression analyses revealed that the CI and HI groups were significantly more likely to report communication in noise compared to the NH group (OR: 2.6 [95% CI 1.4–4.8] and OR: 2.3 [95% CI 1.1–4.7], respectively). This was also the case for distinguishing sounds (OR: 2.4 [95% CI 1.3–4.5] and OR: 2.2 [95% CI 1.1–4.5], respectively), and localisation of sounds (OR: 3.5 [95% CI 1.8–6.8] and OR: 2.8 [95% CI 1.3–5.9], respectively) (see Table 2).

Table 2. Hearing activities, effort, noise, and reverberation.

	CI (n = 98)	HI (n = 52)	NH (n = 54)	CI vs NH/HI vs NH
Hearing activities (categorical)				p value
Detection of sounds, n(%)				.510/.844[a]
Almost never	32 (32.7)	13 (25.0)	15 (27.8)	
Sometimes	39 (39.8)	23 (44.2)	21 (38.9)	
Regularly	20 (20.4)	11 (21.2)	16 (29.6)	
Almost always	7 (7.1)	5 (9.6)	2 (3.7)	
Speech communication in noise, n(%)				**.003/.023[a]**
Almost never	**16 (16.3)**	**13 (25.0)**	**19 (35.2)**	
Sometimes	**42 (42.9)**	**17 (32.7)**	**24 (44.4)**	
Regularly	**29 (29.6)**	**16 (30.8)**	**9 (16.7)**	
Almost always	**11 (11.2)**	**6 (11.5)**	**2 (3.7)**	
Speech communication in quiet, n(%)				
Age category 18 to 50				.405/.592[a]
Almost never	2 (4.8)	2 (7.7)	6 (17.6)	
Sometimes	18 (42.9)	10 (38.5)	6 (17.6)	
Regularly	18 (42.9)	10 (38.5)	15 (44.1)	
Almost always	4 (9.5)	4 (15.4)	7 (20.6)	
Age category 51 to 66				.179/.279[a]
Almost never	7 (12.5)	5 (19.2)	6 (30.0)	
Sometimes	28 (50.0)	11 (42.3)	8 (40.0)	
Regularly	15 (26.8)	6 (23.1)	5 (25.0)	
Almost always	6 (10.7)	4 (15.4)	1 (5.0)	
Distinguishing sounds, n(%)				**.005/.030[a]**
Almost never	**22 (22.4)**	**15 (28.8)**	**25 (46.3)**	
Sometimes	**40 (40.8)**	**17 (32.7)**	**16 (29.6)**	
Regularly	**26 (26.5)**	**15 (28.8)**	**11 (20.4)**	
Almost always	**10 (10.2)**	**5 (9.6)**	**2 (3.7)**	
Localisation of sounds				**<.001/.007[a]**
Almost never	**23 (23.5)**	**18 (34.6)**	**30 (55.6)**	
Sometimes	**52 (53.1)**	**21 (40.4)**	**19 (35.2)**	
Regularly	**20 (20.4)**	**10 (19.2)**	**4 (7.4)**	
Almost always	**3 (3.1)**	**3 (5.8)**	**1 (1.9)**	
Effort, noise, and reverberation				
Effort in hearing, mean (SD; range)	**1.3 (0.6; 0–2.8)**	**1.4 (0.6;0.3–2.7)**	**0.4 (0.5;0.0–2.2)**	**<.001[b]**
Environmental noise, mean (SD; range)	1.1 (0.7; 0–3)	1.1 (0.8; 0–3)	1.0 (0.7; 0–3)	.752[b]
Reverberation, median (25th–75th percentile)	**0.5 (0.0–1.0)**	**0.0 (0.0–1.0)**	**0.0 (0.0–0.5)**	**.023[c]**

[a]Ordinal Regression, [b]One-Way ANOVA, [c]Kruskall–Wallis Test.
Significant effects of group are indicated in bold.



** p < .01

Figure 3. Need for recoveryscores, shown for the CI users, hearing impaired group without CI (HI) and normal hearing group (NH). The scores indicate the mean percentage for each group, the error bars represent the standard deviations. Higher scores indicate more need for recovery.

No significant group differences were found for self-perceived detection of sounds. For speech communication in quiet, we stratified the results as age appeared to be an effect modifier, with lower age being associated with less frequent speech communication in quiet, while the reverse association was observed for the higher age group. Nevertheless, the hearing status groups did not differ with respect to this activity. However, the self-reported effort in hearing differed between groups ($F(2,201) = 46.764$; $p<.001$). Post-hoc analysis revealed that listening effort was significantly higher for the CI group than for the NH group ($p<.001$, 95% C.I. = 0.63–1.11) and also higher for the HI group than the NH group ($p<.001$, 95% C.I. = 0.70–1.26). The CI and HI groups did not differ in their mean listening effort (CI vs. HI, $p=.900$). Significant differences between the groups were also observed for self-perceived reverberation ($p=.023$) (Table 2) with the CI group reporting more reverberation (median 0.5; 0.0–1.0) compared to the NH group (median 0.0; 0.0–0.5) ($p< .05$).

Section 3: working conditions and sick-leave

The three groups differed in their need for recovery ($F(2,201) = 7.04$, $p<.001$). Post-hoc analysis revealed that the mean need for recovery was significantly higher for the HI group (50.7%) than for the NH group (25.8%) ($p<.001$, 95% C.I. = [8.53–39.33]). The NH group had the lowest need for recovery, followed by the CI group (38.5%), though the difference was not significant ($p=.109$). The CI-HI difference was also not significant ($p=.094$), see Figure 3. Finally, the HI group needed more guidance than CI users in managing their HI in the workplace ($p=.003$, OR 4.1, 95% C.I. 1.6–10.7). Results are presented in Table 3.

Sensitivity analysis

Eleven HI participants did not use HAs in daily life. We repeated the analyses using the data of the 41 HA users. The supplementary files present the characteristics (Supplementary Material Table S3) and results (Supplementary Material Tables S4–S6) of each analysis. Similar results as for the main analyses were obtained, but

Table 3. Workplace relationships, support, and sick leave.

	CI (n = 98)	HI (n = 52)	NH (n = 54)	*p* value
Relationship with colleagues, mean (SD; range)	19.8 (13.8; 0–67)	19.6 (13.2; 0–52)	18.5 (13.1; 0–67)	.833[a]
Participation, mean (SD; range)	41.2 (23.4; 0–92)	44.1 (23.9; 0–83)	41.2 (17.4; 0–88)	.718[a]
		n in each category		
Do you need guidance in managing your hearing loss in the workplace? (n no/n yes)	**90/8**	**38/14**	**n.a.**	**.003[b]**
Sick-leave:				
Number of days sick-leave in past 12 months, median (25th–75th percentile)	2.0 (0.0–10.0)	3.5 (0.0–10.0)	1.0 (0.0–4.00)	.125[c]
Sick-leave in past 12 months (n no/n yes)	35/63	20/32	24/30	.572[b]
Reason for sick-leave (n mental distress/n other)	9/54	4/28	2/27	.611[b]

[a]One-Way ANOVA, [b]Wald test, [c]Kruskall–Wallis Test.
Significant group differences are indicated in bold.

the difference in the use of streaming devices between the CI and HA groups was no longer significant, see Supplementary Material Table S3. Furthermore, comparison of the number of supervisory positions between CI, HA and NH participants showed a significant overall effect (p=.045). However, post-hoc analyses revealed there were no significant differences between groups after Bonferroni correction: CI versus HA (p=.261), CI versus NH (p=.054) and HA versus NH ($p = 1.000$).

Discussion

We compared occupational performance of post-lingually deafened CI users with that of a HI and a NH group. We hypothesised that CI users perform worse in occupational settings than HI and NH groups. All analyses were corrected for age, because the CI group was slightly older than the NH group. However, for most outcomes age was neither an effect modifier nor a confounder.

As shown in Figure 2, participants in our study worked in a wide range of workplace environments. Similar to the distribution of Statistics Netherlands, the majority of our participants worked in an office room. In that respect, the current sample can be considered fairly representative of the general Dutch population. The same holds for the tasks at work (Figure 1). The lack of differences between the CI, HI and NH groups in workplace features and job tasks suggests that once enrolled in work, CI recipients seem to integrate well and have equal opportunities.

Unexpectedly, we did not find any differences in work situation, number of working hours, number of workdays per week, type of contract and number of supervisory positions between the three groups. This indicates that hearing status did not affect the main employment characteristics of the participants. This result contrasts with Illg et al. (2017) who reported poorer occupational performance among CI recipients compared to the general population. In contrast to the current study, all participants in the study of Illg et al. (2017) were pre-lingually deaf, implanted in childhood, and received their first CIs between 1986 and 2000. Children implanted today with more up-to-date CIs are expected to have enhanced occupational opportunities compared to that time (Illg et al. 2017).

Consistent with Kramer, Kapteyn, and Houtgast (2006), CI and HI participants reported more frequent speech communication in noise, distinguishing sounds and localising sounds than the NH participants. CI users also reported more reverberation than the NH group. However, the three groups were equally likely to report background noise in the workplace. We assume that these differences in reported hearing activities and reverberation reflect a hearing-loss related increase in the awareness of their acoustical environment or challenging listening activities. Previous research showed that awareness of one's own hearing difficulties is important to overcome the barrier of seeking professional help from an audiologist (Knudsen et al. 2010; Timmer, Launer, and Hickson 2021). In addition, both the CI and HI group experienced higher self-perceived effort in hearing compared to the NH group. Effortful listening is frequently reported by adults with hearing loss (Alhanbali et al. 2017; McCoy et al. 2005; Rönnberg et al. 2013).

Previous studies indicated a relationship between hearing loss and high levels of mental distress and sick-leave in the workplace. However, our research did not confirm this effect, but replicated differences between the groups in the need for recovery after work. The pattern of results was quite surprising. The highest level of need for recovery was observed in the HI group and this was significantly higher than in the NH group. The need for recovery in the HI group approached the cut-off score of 54. In occupational healthcare, this score is indicative of an increased risk for psychosocial health problems (Broersen et al. 2004). The need for recovery of the CI users, averaging 38.5%, was well below this threshold. This is an interesting finding that warrants further research. In addition, significantly fewer CI users reported a need for guidance in managing their hearing loss in the workplace as compared to the HI group. This might be related to the significantly longer duration of hearing loss an/or earlier onset of hearing loss in the CI users. CI users might have learned better coping strategies and/or might have received more guidance in coping with hearing loss. Another explanation may be related to the extensive training that CI recipients receive as part of standard care in the Amsterdam UMC and LUMC. This care is aimed at optimising CI usage, coping with hearing loss and fine-tuning the CI settings. Due to national indication criteria and rehabilitation protocols, the CI outcomes between the centres (Amsterdam UMC and LUMC) can be considered equivalent. Such extensive care is not standard available for individuals with hearing loss (without CI) in the Netherlands, unless patients report hearing difficulties at work or in case of other complicating factors. This explanation is in line with Bosdriesz et al. (2018) who compared the psychosocial health status of CI users with that of individuals with HAs and NH. Their findings indicated that CI users had psychosocial health outcomes comparable to those of the NH group and better outcomes on loneliness and anxiety than HA users. They concluded that CI patients receive more support from caregivers and family or friends, and benefit from better guidance during the rehabilitation after implantation than those fitted with HAs (Bosdriesz et al. 2018).

It can be argued that a comparison between the HI and CI groups is only valid when comparing HI workers who use HAs with those who use CIs. Therefore, we conducted a sensitivity analysis, including only those individuals using HAs in the HI group. Overall, the results were similar to those of the main analyses. Although the difference between CI and HA users in using the direct-streaming functionality of their devices (e.g. for phone calls or online meetings), was no longer significant, still a larger proportion (51.0%) of the CI users reported to use direct-streaming at work

(51% in the CI group vs. 34.1% in the HA users). More frequent use of direct-streaming may have contributed to reduced levels of reported listening effort and reduced levels of need for recovery after work and need for guidance at work in the CI group.

There are some limitations of this study. Firstly, our study results cannot be easily extrapolated to the CI population at large, because we invited CI users who either had a paid job, were engaged in voluntary work, or were enrolled in education. Secondly, we did not have access to speech-in-noise measures which may have been a causal factor in the differences between groups. Previous research shows that there is large inter-individual variability in speech perception among CI users, especially in complex listening conditions (Kaandorp et al. 2015) and more research is needed on the potential contribution of CI outcomes on work performance. Thirdly, a limitation of subjective reports as analysed in the current study is potential individual variability in interpretation of the questions. For example, the answer on the question "Do you need guidance at work in dealing with your hearing loss" could depend on the challenges individuals experience and/or the knowledge individuals have regarding potential strategies.

Conclusions

Hearing status did not affect the main employment characteristics, except for the reported occurrence of several hearing activities. The relatively favourable outcomes of CI users in terms of need for recovery and need for guidance at work might be related to the extensive training and counselling they received as part of their rehabilitation program. Despite the mentioned limitations, this study provides valuable insights as it contributes to an overview of which occupational aspects are affected by hearing status and which are not. This might support CI users and their employers to understand how work performance is affected and provides insights in remaining challenges and opportunities.

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