Cultural Differences in Listening Environments Between Hispanic and White Non-Hispanic Cochlear Implant Users

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ABSTRACT

Objectives: Prior research has shown that, among normal hearing college students, Hispanic-identifying participants experience higher levels of environmental noise and lower signal to noise ratios as compared with White non-Hispanic participants. The primary objective of this study was to examine whether these differences extend to cochlear implant (CI) users by using CI datalogging to quantify characteristics of the listeners' auditory environments. The authors further examined whether differences in auditory environments between groups persisted after controlling for demographic and socioeconomic factors. The primary socioeconomic variable of interest was population density, as it strongly correlates with other socioeconomic factors (e.g., education and income) and is more likely to directly influence auditory environments.

Design: A retrospective chart review of CI patients at a tertiary medical center in New York City identified 80 adults (38 Hispanic, 42 White non-Hispanic) for further review. Demographic variables were compiled, and home addresses were used to obtain population-based socioeconomic data via the U.S. Census. Datalogging information extracted from the CI speech processor included hours of total use and time spent in different auditory environments, classified by the CI software into sound levels (in dBA) and sound scenes ("noise," "quiet," "speech in noise," "speech in quiet," "music," and "other").

Results: Despite similar levels of device usage, there was a statistically significant group difference in the percentage of time spent in each scene: Hispanic-identifying participants spent more time in "speech in noise," "music," and "noise"; White non-Hispanics spent more time in "quiet" and "other." The Hispanic participants lived in census tracts with higher population density, which correlated with higher sound levels (>70 dBA) in the environment. Group differences in auditory environments remained statistically significant after controlling for age, CI experience, and population density (median daily level difference ~2.4 dB).

Conclusions: Even after accounting for demographic and socioeconomic factors, the two groups showed distinct auditory environments, indicating a possible cultural contribution to these differences. Audiologists counseling CI patients regarding auditory environments should be conscious of their patients' cultural background and may consider the impact of listening preferences when advising on which environments to seek out or avoid.

Key words: Auditory ecology, Cochlear implant, Cultural differences.

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INTRODUCTION

In the U.S., 13% of adults have some difficulty hearing, even after being appropriately fitted with a hearing aid (Madans et al. 2021). Cochlear implants (CIs) can help restore hearing in patients with moderate to profound sensorineural hearing loss and increase access to speech and communication. CIs have also been shown to improve social well-being, autonomy, and quality of life (Mäki-Torkko et al. 2015; Contrera et al. 2016; Andries et al. 2021). Newer speech processors include datalogging technology, which can be used to gather and store information about the patient's daily listening experience and provide more accurate information about device usage to assist audiologists in personalized counseling (Cristofari et al. 2018). Researching auditory environments for CI users is important because background noise levels can decrease intelligibility and potentially impair communication (Zeng & Galvin III 1999; Caldwell & Nittrouer 2013). Datalogs can be extracted when the speech processor is connected to the programming software. Datalogging provides information about device usage patterns, time spent in different sound scenes (e.g., speech in noise, speech in quiet, noise, quiet, music, "other"), and the sound level of different environments. Datalogging has been shown to be generally similar to both survey data and personal sound recordings (e.g., Language Environmental Analysis or LENA) (Mauger et al. 2014; Hanvey & DeBold 2015; Ganek et al. 2021).

Despite the availability of this datalogging technology, objective data on auditory environments experienced by CI users are scarce, especially for adults (Busch et al. 2017). There is also a lack of understanding about whether cultural factors that influence auditory environments in normal-hearing listeners (Yu & Kang 2010; Brännström et al. 2012; Fligor et al. 2014) also affect those of CI users. For example, acceptable background noise levels have been shown to vary among different cultures (Brännström et al. 2012; Nguyen et al. 2023). The current work focuses on two of the largest ethnic groups in the U.S. by comparing a self-identified Hispanic group of CI listeners to a self-identified non-Hispanic White group. Research indicates that Hispanic individuals listen to music at higher levels as compared with their White non-Hispanic counterparts and feel that "being loud" is a cultural trait (Ramírez-Esparza et al. 2009, 2019; Fligor et al. 2014; Caraballo 2019). Using LENA sound recorders, Benítez-Barrera et al. (2023) found that Hispanic-identifying college students with normal hearing experienced higher background noise levels and lower signal to noise ratios during periods when speech was detected by the personal sound recorder, compared with their White non-Hispanic peers. This finding may be explained by differences in cultural values, particularly a greater emphasis on collectivism within Hispanic cultures, which prioritizes spending time in groups laughing

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and talking (Rinderle & Montoya 2008; Ramírez-Esparza et al. 2009, 2019; Arevalo et al. 2016). This is in comparison to European Americans, who have been shown to have more individualistic cultural values (Oyserman et al. 2002; Vargas & Kemmelmeier 2013).

A follow-up study by Ramírez-Esparza et al. (2024) using the same dataset demonstrated that collectivist behaviors, such as socializing in groups, mediated the relationship between cultural heritage and nearfield sound levels. Although Hispanic participants in this dataset were more likely to have lower socioeconomic status (SES) than the European American participants, SES was not predictive of collectivistic behaviors, suggesting that preference to be in groups is not determined by SES. However, this study used a coarse, self-reported, Likert scale to index SES, in which the participant self-reported the class of the person(s) who raised them (1 = working class, 2 = lower-middle class, 3 = middle class, 4 = upper-middle class, and 5 = upper class). This index may be insufficient to dissociate relationships between SES, cultural values, and auditory environments.

In the U.S., cultural background and SES are often tightly intertwined. For example, areas with stronger histories of individualistic cultures show higher income mobility, perhaps because of the cultural emphasis on self-improvement (Leonard & Smith 2021). Here, we focus on whether cultural differences in auditory environments persist after accounting for SES, given the known associations between SES and environmental conditions. In population-level studies, environmental noise exposure has been associated with socioeconomic disparity. Dale et al. (2015) found that outdoor noise levels from transportation and industrial sources were greater in socioeconomically disadvantaged areas. Similarly, Casey et al. (2017) used a geospatial model to show that noise levels are higher in areas with higher proportions of non-White and lower SES individuals. Prior work in CI users has also shown SES-related differences in auditory environments. For example, Awad et al. (2023) reported that CI users with private insurance—a proxy for higher SES—spent more time in quiet environments and demonstrated greater daily CI use compared with those with public insurance.

The primary purpose of this study was to use CI datalogging to test the hypothesis that Hispanic CI users experience different daily auditory environments—classified by sound levels and auditory scenes—compared with White non-Hispanic CI users, even after controlling for demographic and SES differences. Understanding how cultural background relates to auditory environments in hearing-impaired individuals is important as it may help promote individualized and culturally conscious healthcare. These two self-identified groups were selected based on the framework established by Benítez-Barrera et al. (2023) and Ramírez-Esparza et al. (2024). Because our dataset was retrospective, cultural values could not be directly measured; therefore, consistent with prior research, ethnicity was used as a proxy for culture, while acknowledging substantial within-group variability in cultural identity. U.S. Census data based on each participant's home address were used to obtain population-based SES measures at the level of the census tract. For the purposes of characterizing group differences in SES, we examined multiple SES metrics, specifically population density, per capita income, percent of population below the poverty line, highest education level achieved, percent foreign-born, percent White non-Hispanic, and percent Hispanic. Of these variables, population density was selected as the covariate in the auditory environment analysis, as it was most likely to have the most direct influence on auditory environments.

MATERIALS AND METHODS

Participants

This study received IRB approval (#i23-01015). Adult patients who underwent cochlear implantation at a tertiary medical center between 2013 and 2023 were included in this study. All participants received a Cochlear Ltd. device and had at least 3 months of CI experience at the time of the data extraction. Only one device manufacturer was used to maintain consistency in the scene analysis algorithm, as between-manufacturer differences exist. Participants were excluded from the chart review if they underwent CI revision surgery, had developmental delays or other cognitive disabilities noted in their medical charts, did not have any follow-up visits, or had less than eight hours of average daily CI use. Among the participants who met criteria, 38 self-identified as Hispanic/Latino on intake forms and had the option of indicating a subgroup (e.g., Puerto Rican and Mexican, see Table 1). These participants (n = 38) comprised the Hispanic group. The comparison group (n = 42) was chosen based on the methodology of Benítez-Barrera et al. (2023), which compared Hispanic and White European American college students. All participants who underwent cochlear implantation during 2017 and identified as White non-Hispanic were included. This year was chosen as it was in the middle of the study period for the Hispanic group. Only those who identified as White non-Hispanic were included in the comparison group, as the number of non-Hispanics within other races in our database was too small for robust analysis. Therefore, all participants who were implanted in 2017, self-identified as White non-Hispanic, and met study inclusion/exclusion criteria were included in the comparison group, a total of 42 participants (80 in the whole group). There were four Hispanic and six White non-Hispanic users who had less than eight hours of average daily CI usage and were thus excluded.

A retrospective chart review was completed by a single researcher in 2024 and replicated by a second researcher in 2025. Demographic data obtained included ethnicity, sex, age at implantation, duration of deafness, etiology of hearing loss, configuration (bimodal: contralateral hearing aid; bilateral: contralateral CI; unilateral: contralateral unaided), type of implant, and whether the appointment was conducted in Spanish (either via interpreter or certified Spanish-speaking provider). Demographic data can be found in Table 1. There were statistically significant group differences detected in sex, duration of deafness before CI, age at CI implantation, hearing loss etiology, or bilateral configuration. The White non-Hispanic group had more CI experience at the time of the data log (median 2.0 years versus 5.8 years, $p = 0.007$), though the medians were well beyond the typical performance plateau point of one year (Lenarz et al. 2012). There was a significant difference in median age at the datalog extraction date ($p = 0.02$), with the Hispanic group being younger in age (at datalog, Hispanic: 63.0 years, White non-Hispanic: 71.3 years). The Hispanic group was heterogeneous, with Puerto Rican and Mexican being the most common subgroups. English was the preferred language for the White non-Hispanic participants, while 39.47% of the Hispanic participants used a Spanish interpreter or a Spanish-speaking

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TABLE 1. Demographic data

	Whole Group (n = 80)	Hispanic (n = 38)	Non-Hispanic (n = 42)	Test Statistics
% Female	58.75%	50%	66.67%	Fisher's exact test, $p = 0.173$
Race	76.25% White, 18.75% Unknown, 5% Other	50% White, 39.47% Unknown, 10.53% Other	100% White	
Ethnicity		Argentinian (1), Colombian (2), Cuban (3), Dominican (6), Mexican (8), Panamanian (2), Puerto Rican (12), Spaniard (1), Unspecified Hispanic/ Latino (3)	100% not of Hispanic origin	
Duration of deafness (yrs)	Median: 20.6, range: 0.8–74.3	Median: 19.8, range: 0.8–70.6	Median: 21.8, range: 0.9–74.3	Mann–Whitney $U = 631.0$, $p = 0.70$
Etiology		Unknown post-lingual (18), genetic (4), unknown congenital (2), infection (2), cholesteatoma (1), Meniere's disease (2), neonatal/prematurity (1), noise exposure (3), autoimmune (1), trauma (1), stroke (1), acoustic neuroma (1), advanced otosclerosis (1)	Unknown post-lingual (20), infection (5), genetic (4), inner ear malformation (3), noise exposure (2), acoustic neuroma (2), advanced otosclerosis (2), unknown congenital (1), Meniere's disease (1), measles (1), trauma (1)	
Age at CI (yrs)	Median: 62.6, range: 19.3–96.0	Median: 59.8, range: 19.3–81.0	Median: 64.10, range: 26.59–96.0	Mann–Whitney $U = 624.0$, $p = 0.10$
Devices		CI24RE-CA (2), CI512/ CI612 (9), CI522 (1), CI532/CI632 (26)	CI24RE-CA (2), CI512 (2), CI522 (3), CI532 (35)	
Configuration		Bilateral (10), bimodal (9), unilateral (19)	Bilateral (14), bimodal (16), unilateral (12)	Chi-square (2 df): 4.02, $p = 0.13$
CI exp. at datalog (ear of study, yrs)	Median: 4.6, range: 0.4–12.7	Median: 2.0, range: 0.4–12.7	Median: 5.4, range: 0.4–8.1	Mann–Whitney $U = 518.0$, $p = 0.007$
Total CI Exp. at datalog (yrs)	Median: 4.8, range: 0.4–25.9	Median: 2.0, range: 0.4–12.7	Median: 5.8, range: 0.4–25.9	Mann–Whitney $U = 492.0$, $p = 0.003$
Age at datalog (yrs)	Median: 67.0, range: 20.4–97.7	Median: 63.0, range: 20.4–87.4	Median: 71.3, range: 27.4–97.7	Mann–Whitney $U = 554.0$, $p = 0.02$
Duration of datalog (days)	Median: 182.0, range: 41.0–713.0	Median: 182.6, range: 41.0–713.0	Median: 181.5, range: 57.9–372.0	Mann–Whitney $U = 784.0$, $p = 0.89$
% Using Spanish interpreter		39.47%	0%	
CI usage (hrs)	Median: 13.0, range: 8.4–16.6	Median: 12.7, range: 8.4–16.6	Median: 13.4, range: 8.4–15.8	Mann–Whitney $U = 663.0$, $p = 0.20$

CI, cochlear implant.

audiologist for their audiology appointments. Data about bilingualism were not available for this dataset.

SES Variables

U.S. Census data based on each participant's home address were used to obtain population-based SES measures at the level of the census tract. A census tract is a small geographic area that encompasses an average of 4000 people (US Census Bureau 2022). The population-based SES metrics of interest included population density, per capita income, percent of population below the poverty line, highest education level achieved, percent foreign-born, percent White non-Hispanic, and percent Hispanic.

For the purposes of characterizing group differences in SES, we report descriptive statistics for each variable but focus on population density as a primary covariate when analyzing group differences in auditory environments. Three participants (two Hispanic, one White non-Hispanic) did not have U.S. addresses at the time of the data extraction (although they had previously lived in the U.S.) and were thus excluded from socioeconomic data analysis. Table 2 reports population-based statistics derived from U.S. Census data based on the participants' home addresses. The Hispanic group lived in areas with significantly higher population density, percentage of individuals with income levels below the poverty line, percentage foreign born, and percentage Hispanic (all $p < 0.001$). The White non-Hispanic group lived in areas with significantly higher per capita income ($p = 0.003$), percentage with a high school degree or more ($p < 0.001$), percentage with a Bachelor's degree or more ($p = 0.02$), and percentage White non-Hispanic ($p < 0.001$). In addition, White non-Hispanics lived in communities with a significantly higher median age of residents ($p = 0.002$). Given a high correlation between these census-derived variables and the focus of our study being on auditory environments, all further analyses focused only on population density, as the number of people per geographic unit is presumed to have the most direct

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TABLE 2. Socioeconomic status measures (from U.S. Census data)

	Whole Group, Median (Range)	Hispanic, Median (Range)	Non-Hispanic, Median (Range)	Test Statistics
Population density (people per square mile)	18,259.3 (32.6–170,638.8)	49,321.9 (212–170,638)	6408.3 (32.6–10,1934.8)	Mann–Whitney *U* statistic = 319.0, $p < 0.001$
Median age (yrs)	41.4 (15.7–69.9)	39.4 (31.2–50)	43.5 (15.7–69.9)	Mann–Whitney *U* statistic = 437.0, $p = 0.002$
Per capita income (U.S. $)	54,249 (15,014–248,776)	40,770.5 (15,014–197,211)	58,610.0 (15,082–248,776)	Mann–Whitney *U* statistic = 442.0, $p = 0.003$
% Below poverty line	7.9 (0.6–48.2)	15.5 (0.6–48.2)	5.1 (0.8–30.3)	Mann–Whitney *U* statistic= 313.5, $p < 0.001$
% With high school degree or more	94.9 (29.2–99.5)	84.7 (29.2–99.4)	95.7 (78.5–99.5)	Mann–Whitney *U* statistic= 290.5, $p < 0.001$
% With Bachelor's degree or more	44.1 (9.4–91.2)	27.1 (9.7–90.8)	48.7 (9.4–91.2)	Mann–Whitney *U* statistic= 426.0, $p = 0.001$
% Foreign born	20.8 (0.8–66.4)	31.2 (2.4–63.0)	13.7 (0.8–66.4)	Mann–Whitney *U* statistic= 362.5, $p < 0.001$
% White non-Hispanic	64 (0–98)	22 (0–88)	79.0 (31–98)	Mann–Whitney *U* statistic= 188.5, $p < 0.001$
% Hispanic	12 (0–83)	29 (1–83)	9.0 (0–26)	Mann–Whitney *U* statistic = 280.0, $p < 0.001$

Columns represent values for the population in the census tract of each participant's home address.

influence on environmental sound levels relative to the other SES variables (Casey et al. 2017; Cai et al. 2019). It is important to note that because some of these data are not directly reported by the participants (e.g., income level), there may be significant variations at the individual level. However, the primary variable of interest in our study, population density at each participant's home address, was directly reported and specific to the individual.

CI Usage and Auditory Environment Patterns

At our CI center, it is protocol to extract datalogging from the user's sound processor at each mapping appointment by connecting it to the programming software. Datalogs were extracted from Cochlear's software (Custom Sound Pro) using software provided by Cochlear Ltd. The reports include all data accrued since the last audiology visit, aggregated over time. Metrics are recorded by the microphone only when the sound processor is on. The environmental sound inputs are classified and binned based on sound level (<40, 40 to 50, 50 to 60, 60 to 70, 70 to 80, and >80 dBA) and scene (speech in noise, speech in quiet, quiet, music, noise, and "other"). While the specifics of the scene classifier are proprietary, the algorithm uses ranges of decibel levels, signal to noise ratio, and spectral and temporal characteristics of the signal, which are used for sound classification purposes (Ganek et al. 2021). The average daily time spent in each of the auditory environments as well as the average overall device usage time is reported in Table 1 in Supplemental Digital Content, https://links.lww.com/EANDH/B979. For the present study, only data that were extracted from the participant's most recent follow-up were included in the analysis, with two exceptions: datalogs that included time between March 1, 2020, and December 31, 2021, were excluded from analysis, as this was during the peak of the COVID-19 pandemic and social distancing guidelines may have affected environmental noise levels (Knickerbocker et al. 2021). Datalogs were also excluded if they were less than 30 days in duration. In these cases, the second-most recent datalog was chosen. For participants who wore multiple processors on the same ear during the analysis window, the time output was added across successively worn processors. For participants who had bilateral implants, the time was averaged across the two processors.

There was no statistically significant difference in average daily CI usage (Hispanic median: 12.7 hr, White non-Hispanic median: 13.4 hours, $p = 0.20$). The median length of the datalog was similar for both groups (Hispanic: 182.6 days, White non-Hispanic: 181.5 days, $p = 0.89$). For each participant, the midpoint date of their data log date range was calculated. For the Hispanic group, the range of dates was August 2015–April 2025, and the group median date was June 14, 2023. For the White non-Hispanic group, the range of dates was August 2017–September 2024, and the group median date was December 25, 2022. These analyses suggest the datalogs reflect similar dates and lengths of time across groups.

Statistical Analysis

To obtain a single value representing daily sound exposure, the estimated median overall daily sound level was calculated by assigning the value "35 dBA" to the category "<40 dBA" and "85 dBA" to the category ">80 dBA," then calculating the cumulative percentage of time at each level. The levels of 35 and 85 dBA were chosen to represent all levels below 40 dBA or above 80 dBA, respectively. Because the median level was calculated, the exact levels of the lowest and uppermost categories are less contributory. The median dBA level was linearly interpolated from the two adjacent categories. The percentage of total time in each auditory scene was analyzed as it accounts for differences in daily usage time. The percentage of time was calculated by dividing the average number of hours per day in each scene by the average total hours of usage per day. This was repeated for each sound level category. Given that both groups spent less than 2% of the day in environments >80 dBA, this category was combined with the 70 to 80 dBA category to create a ">70 dBA" category that was used for all other analyses. All analyses with auditory environment time were performed twice: once using raw hours and once using the percentage of time in each scene (speech in noise, speech in quiet, quiet, music, noise, or other)

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or each level category (<40, 40 to 50, 50 to 60, 60 to 70, >70 dBA).

We first present an analysis of how auditory environments relate to demographic variables (age, sex, years of CI experience, duration of deafness) and population density using Pearson's correlations. Rom's method (Rom 1990) was used to correct for multiple comparisons. We also examined differences in auditory environment as a function of listening configuration using the Kruskal–Wallis test because of the non-normal distribution of the data.

Next, two-tailed independent *t*-tests were used to compare time spent in each sound level and sound scene between the Hispanic and White non-Hispanic groups. In cases where the data were not normally distributed, the Mann–Whitney test was used instead. Last, to test our primary hypothesis, multiple analyses of variance were used to compare groups on auditory environments while covarying population density and demographic variables. Population density was log-transformed for correlational analyses, multiple analyses of variance, and linear regressions, as it followed an exponential growth pattern.

RESULTS

Relation of Auditory Environments to Demographic and Population Density

Participant age at the time of the data log extraction was negatively correlated with median daily sound level ($r = -0.40$, $p < 0.001$), the percentage of time spent in environments >70 dBA ($r = -0.62$, $p < 0.001$), and the percentage of time spent in music ($r = -0.35$, $p = 0.001$). Age was positively correlated with the percentage of time spent in quiet ($r = 0.30$, $p = 0.006$). Similar results were found when environments were considered as raw hours: there was a negative correlation between age and time in environments >70 dBA ($r = -0.61$, $p < 0.001$) and the music scene ($r = -0.37$, $p < 0.001$). There was a significant negative correlation between the total years of CI experience and the amount of time spent in noise (calculated as either a percentage: $r = -0.31$, $p = 0.005$ or raw hours: $r = -0.30$, $p = 0.006$), though upon visual inspection this correlation appears to be driven by a single outlier. With this outlier removed, there was no statistically significant relationship. The effect of configuration (unilateral, bimodal, or bilateral) was examined using a Kruskal–Wallis test because of non-normal distribution of the data. A significant effect of configuration was found for time spent in environments <40 dBA (both hours and percentage of time: $p < 0.001$). Post hoc analyses found that participants in the unilateral configuration spent fewer hours in this environment than bimodal or bilateral participants ($p < 0.003$); there was no significant difference between bimodal and bilateral CI users ($p = 0.55$). No significant correlations were detected between duration of hearing loss, and Mann–Whitney tests found no significant effect of sex on any measure of auditory environment.

Next, we examined the population density metric from the census data to determine if there was a relationship with auditory environments (Fig. 1). Population density was negatively correlated with hours <40 dBA ($r = -0.36$, $p = 0.002$), 40 to 50 dBA ($r = -0.31$, $p = 0.005$), and quiet ($r = -0.43$, $p < 0.001$, panel B); it was positively correlated with noise ($r = 0.40$, $p < 0.001$, panel D). Similar results were seen for categories as a percentage of time: there were negative correlations between population density and <40 dBA ($r = -0.31$, $p = 0.006$), 40 to 50 dBA ($r = -0.32$, $p = 0.004$), and quiet ($r = -0.40$, $p < 0.001$, panel A); there were positive correlations between population density and environments 50 to 60 dBA ($r = 0.30$, $p = 0.01$) and noise ($r = 0.42$, $p < 0.001$, panel C).

Group Comparisons

The estimated median daily sound level was 51.4 dBA for the Hispanic group and 46.8 dBA for the White non-Hispanic group, a statistically significant difference [$t(78) = 4.5$, $p < 0.001$] (Fig. 2). Fig. 3A, C show the median percentage of time per day and raw hours per day in each sound level category, respectively. Using Mann–Whitney tests because of the non-normal distribution of the data, we found that White non-Hispanic participants spent a higher percentage of time in environments <40 dBA (Hispanic: 9.7%, White non-Hispanic: 17.3%; $p < 0.001$) and 40 to 50 dBA (Hispanic: 20.3%, White non-Hispanic: 25.4%, $p = 0.001$). Hispanic participants spent a higher percentage of time in environments 60 to 70 dBA (White non-Hispanic: 20.5%, Hispanic: 24.4%, $p = 0.005$) and >70 dBA (White non-Hispanic: 7.9%, Hispanic: 12.9%, $p = 0.007$). In terms of hours per day, similar results were found. White non-Hispanic participants spent more hours per day in environments <40 dBA (White non-Hispanic: 2.2; Hispanic: 1.2, $p < 0.0001$) and 40 to 50 dBA (White non-Hispanic: 3.3, Hispanic: 2.6, $p < 0.001$). Hispanic participants spent more time in environments >70 dBA (Hispanic: 1.6, White non-Hispanic: 1.07, $p = 0.02$). There were no group differences detected for the percentage or hours of time in 50 to 60 dBA environments or hours of time in 60 to 70 dBA environments.

Fig. 3B, D show the median percentage of time per day and raw hours per day in each scene classification, respectively. Hispanics spent a significantly higher percentage of time in speech in noise (Hispanic: 25.6%, White non-Hispanic: 20.4%, $p = 0.003$), noise (Hispanic: 20.1%, White non-Hispanic: 16.0%, $p = 0.005$), and music (Hispanic: 4.3%, White non-Hispanic: 2.2%, $p < 0.001$). White non-Hispanic participants spent a significantly higher percentage of time in quiet (Hispanic: 30.4%, White non-Hispanic: 47.9%, $p < 0.001$) and "other" (Hispanic: 0.04%, White non-Hispanic: 2.4%, $p = 0.02$). In terms of hours, Hispanic participants spent significantly more time in noise (Hispanic: 2.7, White non-Hispanic: 2.0, $p = 0.006$) and music (Hispanic: 0.5, White non-Hispanic: 0.3, $p = 0.001$). White non-Hispanic participants spent significantly more time in quiet (Hispanic: 3.8, White non-Hispanic: 6.4, $p < 0.001$) and "other" (Hispanic: 0.0, White non-Hispanic: 0.4, $p = 0.02$). There were no group differences detected for the percentage of time or raw hours in speech in quiet. All auditory environment data are shown in Table 1 in Supplemental Digital Content, https://links.lww.com/EANDH/B979.

Given the significant effects of age and CI experience on auditory environments found earlier, and differences in our dataset between the Hispanic and White non-Hispanic group on age and years of CI experience, multivariate analyses were performed to determine if the groups (fixed factor: Hispanic versus White non-Hispanic) significantly differed in auditory environment while controlling for age and CI experience (covariates). Configuration (unilateral, bimodal, bilateral) was not included as a covariate because it was found to only affect one auditory

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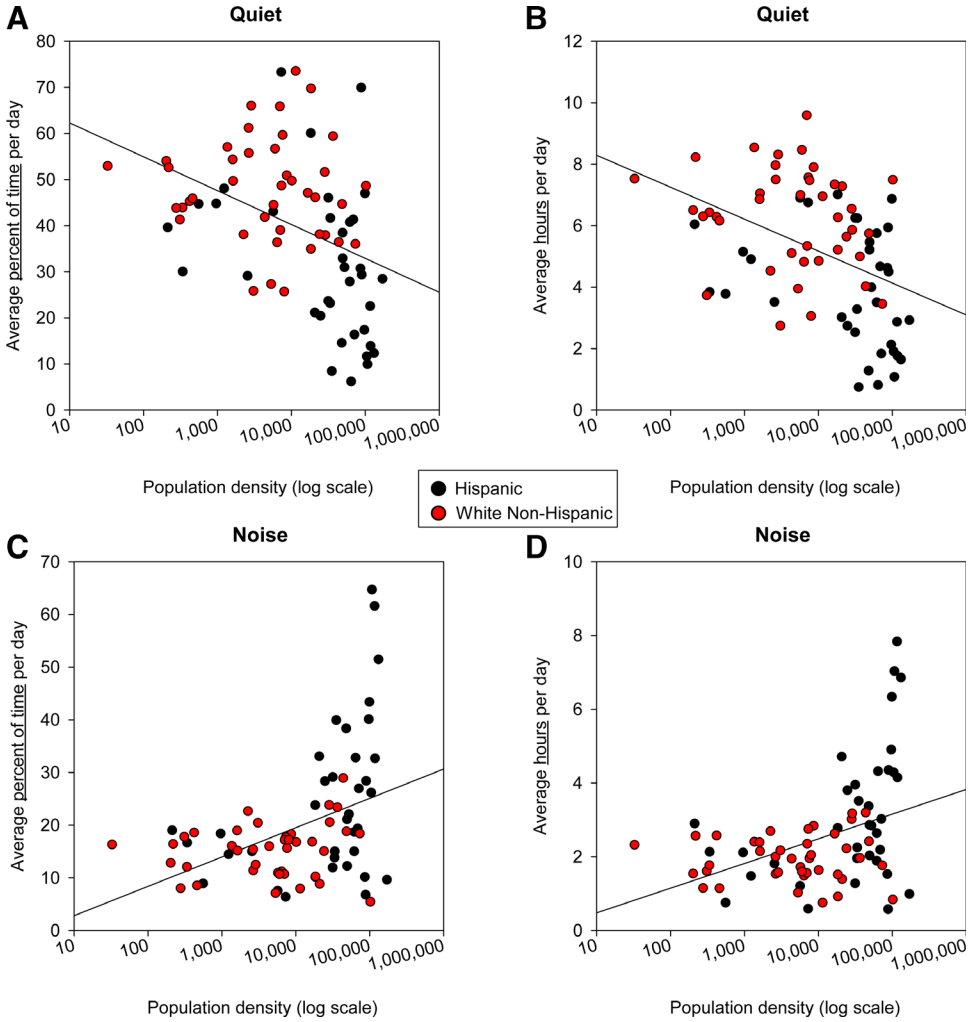


Fig. 1. Regressions between population density (x axis, log scale) and the average percentage of time (panels A and C) or hours per day (panels B and D) in quiet (panels A and B) and noise (panels C and D). Individual data points are shown for the Hispanic (black) and White non-Hispanic (red) groups.

environment (<40 dBA) and did not differ across the groups. Each set of dependent variables was run separately (auditory environment levels in percentage of time, scenes in percentage of time, auditory environment levels in hours, and scenes in hours). Results are reported in Table 3. Significant group differences remained for all models. Between-subject effects revealed differences between groups for environments <40, 40 to 50, 50 to 60, 60 to 70 (percentage only), and >70 dBA, as well as the speech in noise, quiet, music, and noise scenes. To give an overall measure of group differences, a univariate analysis was run with the same fixed factor (group) and covariates using median daily level as a dependent variable. There was a significant main effect of group [$F(1,76) = 13.86$, $p < 0.001$], with the Hispanic group listening in higher-intensity environments than the White non-Hispanic group (adjusted mean difference: 3.37 dBA, SE: 0.91 dBA).

Given that the groups also differ significantly on population density, we repeated the multivariate analyses, adding population density as a covariate along with age and years of CI experience at the time of the data log extraction. Results are reported in Table 4. Significant group differences remained for all models except levels as a percentage of time per day. Between-subject effects revealed differences between groups for environments <40, 40 to 50 (hours only), and 50 to 60 dBA (percentage only), as well as the speech in noise (percentage only), quiet, and music scenes. A univariate analysis was run with the same fixed factor (group) and covariates (age, years of CI experience, population density) using median daily level as a dependent variable. There was a significant main effect of group [$F(1,72) = 5.39$, $p = 0.02$], with the Hispanic group listening in higher intensity environments than the White non-Hispanic group (adjusted mean difference: 2.35 dBA, SE: 1.01 dBA). These results suggest that after accounting for differences in age, CI experience, and population density, the groups experienced small but statistically significantly different auditory environments.

DISCUSSION

In a sample from a tertiary medical center in New York City, this study sought to characterize differences in everyday auditory environments between self-identifying Hispanic and White non-Hispanic CI listeners. Using a retrospective chart review design, we compared daily auditory environments (via speech processor datalogging), demographics, and socioeconomic

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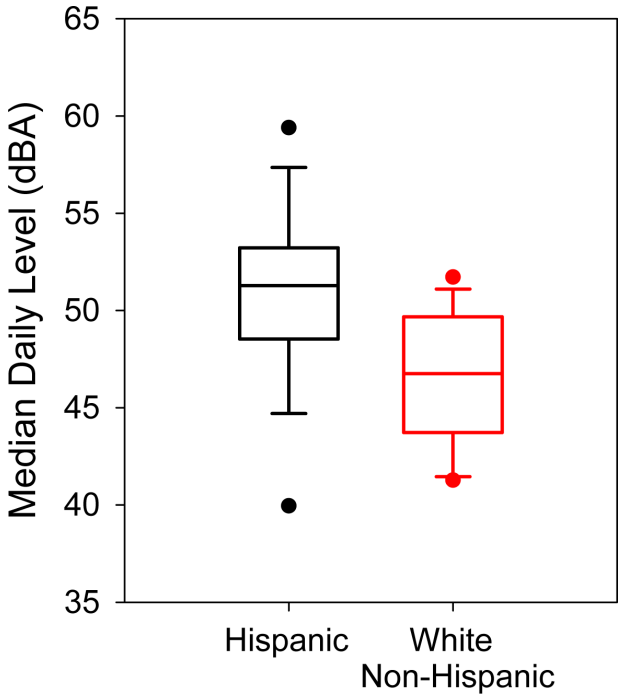


Fig. 2. Calculated median daily level for the Hispanic (black) and the White non-Hispanic group (red). Points represent 5th/95th percentile.

variables (via U.S. Census data) between study groups. Our study aims and hypotheses were guided by prior evidence of cultural influences on listening preferences for young adults with normal hearing (Benítez-Barrera et al. 2023; Ramírez-Esparza et al. 2024).

Comparing Auditory Environments for Hispanic and White Non-Hispanic CI Users

Our analyses found significant differences in auditory environments between Hispanic and White non-Hispanic CI study participants. Hispanic participants in the sample experienced significantly louder environments (higher dB levels) compared with White non-Hispanic participants (median daily level: 51.4 versus 46.8 dBA, $p < 0.001$). Specifically, Hispanic participants spent more time in environments >70 dBA, speech in noise, noise, and music, while White non-Hispanic participants spent more time in quieter environments (<40 dBA, 40 to 50 dBA, quiet). There was no significant difference between groups for the speech in a quiet environment. These findings are in agreement with Benítez-Barrera et al. (2023), who found that Hispanic college students experienced average noise levels 0.75 dBC higher than their White non-Hispanic counterparts. It is important to note that the earlier study used a different methodology, the LENA recording device, which is not directly comparable to CI datalogging: dBC frequency weighting with the LENA recording device versus dBA weighting by the CI sound processor used in the present study. To our knowledge, there are no studies objectively examining auditory environments between Hispanic and non-Hispanic adults with CIs, either with CI datalogging or another personal sound measurement technique. Indeed, most studies that use CI datalogging have included very few Hispanic participants (Awad et al. 2023; Wu et al. 2025).

We also considered how potential confounding factors may influence our findings. Considering all participants together, we found that age was negatively correlated with the amount of time spent in higher-intensity environments, similar to prior studies (Chow et al. 2021; Awad et al. 2023; Wu et al. 2025). We also found significant correlations between population density and auditory environments, such that regardless of group, participants living in dense areas were more likely to spend less time in quiet and more time in noise. Previous studies have shown higher environmental noise exposure for areas with higher population density, typically based on modeling that encompasses both measured noise levels and geospatial features known to contribute to noise, such as airports, roadways, or industry (Casey et al. 2017; Cai et al. 2019). To our knowledge, there are no other studies that report a relationship between these variables for CI listeners.

There were also differences between the Hispanic and White non-Hispanic groups on demographic and socioeconomic variables, motivating their inclusion as covariates when testing our primary hypothesis. The Hispanic group had a lower median age, less CI experience, and a higher median population density. Prior studies have also demonstrated racial and ethnic differences in population density (Dale et al. 2015; Casey et al. 2017; Martin et al. 2017), so this finding was not unexpected. We found that differences in median daily sound level, as well as time in quiet, speech in noise, and music, persisted after controlling for age, CI experience, and population density, suggesting that the auditory environment may be, at least in part, culturally influenced.

The results reported in the present study, however, are unlikely to be due to differences in ethnicity or culture alone. Factors such as personality, social network size, and sociocultural values may play an important role. These variables are unaccounted for in a retrospective analysis. While our dataset does not allow us to directly test whether preferences for cultural collectivism predict the Hispanic group's higher median sound level, time in speech in noise, and time in music, the pattern of results is broadly consistent with behaviors seen among collectivist societies that inherently result in louder environments and more time spent in groups. In the present study, we also found a positive correlation between time spent in noise and population density (Fig. 1, bottom panels). Upon visual examination, the Hispanic and White non-Hispanic groups follow different patterns: the White non-Hispanic group demonstrates a linear relationship between both variables, whereas the Hispanic group shows an exponential pattern. At high levels of population density, there is little relationship between time spent in noise and population density in the Hispanic group, suggesting that cultural values may influence time spent in this auditory environment more so than population density. Said differently, the pattern in Fig. 1 suggests that the relationship between ethnicity and auditory environments may exist across the socioeconomic strata. This aligns with the conclusions of Ramírez-Esparza et al. (2024), who examined auditory environments and collectivistic values for normal-hearing Hispanic and White non-Hispanic college students using the same dataset as Benítez-Barrera et al. (2023). The authors found that collectivistic behaviors (e.g., socializing) mediated the relationship between cultural heritage and auditory environments. It is important to note that, relevant to our current findings, in the study by Ramírez-Esparza et al., no correlation was detected

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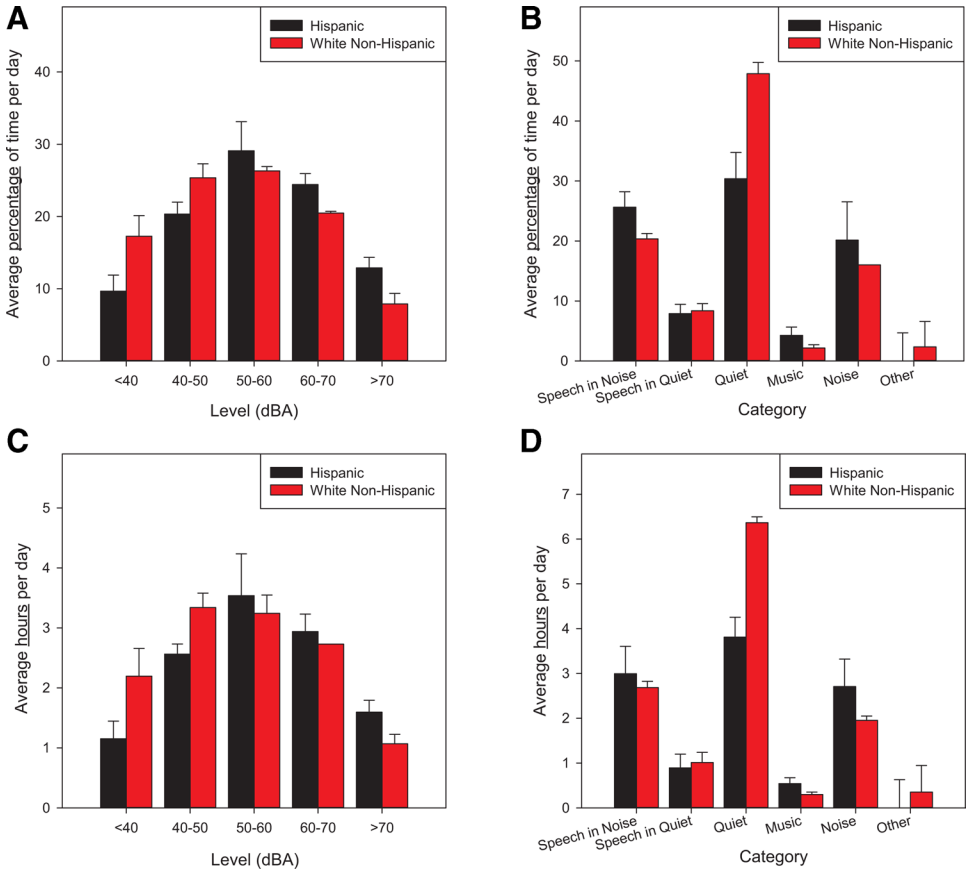


Fig. 3. Median usage time, expressed as the average percentage of total daily listening time (panels A and B) or the average number of hours per day (panels C and D), is shown for the Hispanic group (black) and White non-Hispanic group (red) as a function of sound level (panels A and C) or scene classification (panels B and D). Error bars represent 1 SE.

between self-reported SES and collectivistic behavior, suggesting that SES is not predictive of cultural preferences and behaviors for these participants. We note that we used a different approach to indexing auditory-relevant dimensions of SES than the work by Ramírez-Esparza et al., which used a simple Likert scale in which the participant self-reported the class of the person(s) who raised them.

Limitations

There are several limitations in this study. First, our choice of groups and hypotheses regarding the impact of cultural values on auditory environments was based on prior work by Benítez-Barrera et al. (2023) and Ramírez-Esparza et al. (2024). We acknowledge that collectivistic values may be promoted in other ethnic groups, which could be studied in future work. Second, the retrospective nature of the study resulted in missing data points for population density metrics for multiple participants. Details on how scenes are classified are proprietary to Cochlear Ltd., making it difficult to know if the classification is accurate and generalizable to other CI manufacturers. Data are also summed across the entire log period and averaged over each day, making it difficult to analyze on a granular level, although this approach makes it less likely to be skewed by outliers. Future studies might examine smaller log lengths to assess seasonal effects or use non-CI-specific datalogging equipment, such as the LENA technology. It is also important to note that sounds heard via streaming or direct audio input are not captured in these data. While this is a limitation, we note that the purpose of this study was to analyze environmental sound level and not all listening conditions. We also acknowledge that the groups were not completely age-matched at the time of the data log extraction and that there are potential cohort differences that arose from our approach to forming groups. Specifically, the White non-Hispanic participants were all implanted in a single year (2017) at the midpoint of the years the Hispanic participants were implanted (2013–2023). However, all datalog extractions were done at their most recent clinic visit, and the median midpoint dates of the datalog extractions were ~6 months apart. Future studies could include a White non-Hispanic sample implanted in many different years. Last, the socioeconomic analysis focused only on home addresses, but this location is likely to constitute only a portion of a person's daily environment and does not fully represent their SES. Future prospective studies could determine how other aspects of a patient's daily life, such as job, household structure, SES, and social life, relate to auditory environments and speech perception.

Despite these limitations, we believe our study contributes valuable knowledge regarding auditory environments for Hispanic CI users, a highly underrepresented population in the literature. This study paves the ground for a more systematic and prospective evaluation of the multiple variables that might contribute to a CI user's auditory environment. More research is also needed to understand whether auditory environment

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TABLE 3. Multivariate analysis of group on listening environment; covariates: age, CI experience

Multivariate Tests				
	Pillai's Trace	*F*	df	Sig. (*p*)
Level (hr)	0.303	6.25	5, 72	<0.001
Scenes (hr)	0.334	5.94	6, 71	<0.001
Level (%)	0.249	4.785	5, 72	<0.001
Scenes (%)	0.329	5.794	6, 71	<0.001
Between-Subject Effects				
		F	df	Sig.
Level (hr)				
<40 dBA		17.70	1, 76	<0.001
40 to 50 dBA		11.10	1, 76	0.001
50 to 60 dBA		5.43	1, 76	0.022
60 to 70 dBA		2.60	1, 76	0.111
>70 dBA		4.49	1, 76	0.037
Scenes (hr)				
Speech in noise		5.23	1, 76	0.025
Speech in quiet		0.13	1, 76	0.718
Quiet		25.76	1, 76	<0.001
Music		12.64	1, 76	<0.001
Noise		9.51	1, 76	0.003
Other		0.98	1, 76	0.324
Level (percentage of time)				
<40 dBA		14.13	1, 76	<0.001
40 to 50 dBA		9.73	1, 76	0.003
50 to 60 dBA		10.47	1, 76	0.002
60 to 70 dBA		5.17	1, 76	0.026
>70 dBA		5.55	1, 76	0.021
Scenes (percentage of time)				
Speech in noise		9.77	1, 76	0.003
Speech in quiet		0.05	1, 76	0.829
Quiet		20.69	1, 76	<0.001
Music		13.53	1, 76	<0.001
Noise		10.64	1, 76	0.002
Other		0.879	1, 76	0.351

Four separate multivariate analyses are shown along with univariate tests for each.
CI, cochlear implant.

TABLE 4. Multivariate analysis of group; covariates: age, CI experience, pop. density

Multivariate Tests				
	Pillai's Trace	*F*	df	Sig. (*p*)
Level (hr)	0.189	3.172	5, 68	0.012
Scenes (hr)	0.215	3.058	6, 67	0.011
Level (%)	0.143	2.27	5, 68	0.06
Scenes (%)	0.231	3.354	6, 67	0.006
Between-Subject Effects				
		F	df	Sig.
Level (hr)				
<40 dBA		9.18	1, 72	0.003
40 to 50 dBA		4.55	1, 72	0.036
50 to 60 dBA		2.07	1, 72	0.154
60 to 70 dBA		0.64	1, 72	0.428
>70 dBA		2.08	1, 72	0.154
Scenes (hr)				
Speech in noise		2.40	1, 72	0.127
Speech in quiet		0.002	1, 72	0.962
Quiet		12.62	1, 72	<0.001
Music		8.10	1, 72	0.006
Noise		3.23	1, 72	0.076
Other		0.94	1, 72	0.335
Level (% of time)				
<40 dBA		7.24	1, 72	0.009
40 to 50 dBA		3.10	1, 72	0.083
50 to 60 dBA		4.40	1, 72	0.039
60 to 70 dBA		1.89	1, 72	0.174
>70 dBA		2.70	1, 72	0.105
Scenes (% of time)				
Speech in noise		5.19	1, 72	0.026
Speech in quiet		0.31	1, 72	0.862
Quiet		9.37	1, 72	0.003
Music		9.29	1, 72	0.003
Noise		3.64	1, 72	0.061
Other		0.86	1, 72	0.356

Four separate multivariate analyses are shown along with univariate tests for each.
CI, cochlear implant.

differences meaningfully influence real-world communication and CI speech outcomes, and whether those relationships are moderated by culture. Time spent in challenging auditory environments, such as speech in noise, may represent an opportunity for long-term, naturalistic auditory training and therefore improve CI speech perception measures (if they are appropriately realistic). However, cultural values may influence both the specifics of the auditory environment (e.g., multiple languages present, number of talkers) and the degree to which the individual engages in conversation (e.g., their role in the family structure and tendency toward sociability); these variables may play a mediating role. This line of research will also help provide better clinical recommendations as to which auditory environments may be most beneficial for which CI outcomes and for which individuals. For example, patients could be encouraged to seek out specific auditory environments, or if they are already in these environments, actively participate in them to the degree it is culturally appropriate to do so.

CONCLUSION

In this study, we analyzed the auditory environments of CI users and found that Hispanic study participants spend more time in speech in noise, noise, and music compared with White non-Hispanic participants. The Hispanic sample also had a 4.6 dB higher median environmental sound level. This difference remained statistically significant even after controlling for population density and demographic variables such as age and CI experience, suggesting there may be a cultural component to the group differences in auditory environments. However, it should be noted that the clinical or perceptual relevance of this difference is unknown, and the estimated marginal mean difference between the groups after controlling for covariates was smaller (2.4 dB). While current clinical approaches often emphasize avoiding background noise to optimize listening capabilities in patients with CIs, our findings demonstrate that noise can be an integral part of a person's life, such as for those living in densely populated areas or for those who enjoy spending time in groups. Therefore, blanket recommendations to avoid background noise are not only unrealistic for some, but they may go against cultural preferences, lifestyle choices, or unavoidable noise exposure because of population density. Clinical counseling should take this into account to ensure that recommendations are aligned with socioeconomic and cultural factors, as well as individual preferences. Examples of this could include validating the auditory environment experience reported by Hispanic CI users, providing culturally sensitive communication strategies,

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or emphasizing the use of assistive listening technologies such as remote microphones.

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E.R.S. and E.S. designed the experiments, with input from S.B.W. and M.M.T. A.J.L. and E.R.S. collected and analyzed the data. A.J.L. wrote the manuscript. All authors discussed the results and provided critical editing to the manuscript at all stages.

The authors have no conflicts of interest to disclose.

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