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JASA ARTICLE

Effects of cultural dynamics on everyday acoustic environments[a)]

Nairán Ramírez-Esparza,[1,b)] Shu Jiang,[2] Adrián García-Sierra,[3] Erika Skoe,[3] and Carlos R. Benítez-Barrera[4,5]
[1]*Department of Psychological Sciences, University of Connecticut, Storrs, Connecticut 06269-1020, USA*
[2]*Psychology Department, St. Lawrence University, Canton, New York 13617, USA*
[3]*Department of Speech, Language and Hearing Sciences, University of Connecticut, Storrs, Connecticut 06269-1085, USA*
[4]*Department of Communication Sciences and Disorders, University of Wisconsin—Madison, Madison, Wisconsin 53706, USA*
[5]*Waisman Center, University of Wisconsin—Madison, Madison, Wisconsin 53705, USA*

ABSTRACT:
Differences in acoustic environments have previously been linked to socioeconomic status (SES). However, it is crucial to acknowledge that cultural values can also play a significant role in shaping acoustic environments. The goal of this study was to investigate if social behaviors related to cultural heritage and SES could help us understand how Latinx and European college students in the U.S. have different acoustic environments. College students were given digital recorders to record their daily acoustic environments for two days. These recordings were used to (1) evaluate nearfield noise levels in their natural surroundings and (2) quantify the percentage of time participants spent on behavioral collectivistic activities such as socializing and interacting with others. Behavioral collectivism was examined as a mediator between cultural heritage, SES, and nearfield noise levels. Findings revealed that both SES and cultural heritage were associated with nearfield noise levels. However, behavioral collectivism mediated the relationship between culture and nearfield noise levels. These findings show that collectivist cultural norms significantly relate to Latinx' daily noise levels. The implications of these findings for public health and health inequities included promoting equitable auditory well-being and better knowledge of socio-cultural settings.
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I. INTRODUCTION

In September 2022, Xochitl Gonzalez published an article in the Atlantic titled "Why do rich people love quiet? The sound of gentrification is silence" (Gonzalez, 2022). In this article, Gonzalez vividly recounts her experiences growing up in Brooklyn. She noted that her childhood's once vibrant and bustling neighborhood was gradually transformed into a quieter environment, which she attributed to gentrification and wealth. Interestingly, she found a similar dynamic when she left home to study at an Ivy League college. Upon her arrival at campus for the minority-student orientation, she spent her first evenings chatting and dancing until late in the dormitory among fellow minority students. However, when the non-minority students arrived a few days later, the campus grew quiet. This made Gonzalez reflect on the extent to which culture and wealth might shape preferences for different types of acoustic environments. Her intuitions echo research that has shown that acoustic environments are different between cultures (Benítez-Barrera *et al.*, 2023) and that these differences may be caused, at least in part, by the way people act in social situations that are unique to each culture (Ramírez-Esparza *et al.*, 2012). Interestingly, Gonzalez also highlights an inherent challenge to cultural research. Culture and socioeconomic status (SES) are tightly intertwined in the U.S., to the point that it is not always feasible to separate one from the other (e.g., Kawachi *et al.*, 2005). Assuming this inherent limitation, in this study, we aimed to elucidate whether social behaviors that relate to cultural heritage and SES are associated with differences in acoustic environments between college students of Latinx and European heritage. This study provides new information on how social behaviors might shape acoustic environments and the diverse and nuanced ways in which individuals from different backgrounds engage with their environments. This information could be used in the future to understand health outcomes as they relate to cultural acoustic environments.

Environmental noise can be associated with multiple factors. For example, it is well known that low-SES neighborhoods, in which minority groups are overrepresented, have higher levels of noise pollution than wealthy neighborhoods (Casey *et al.*, 2017; Dale *et al.*, 2015; Haines *et al.*, 2002; deSouza *et al.*, 2022; Trudeau *et al.*, 2023). Individuals from low-SES backgrounds are also more likely to work in loud environments (e.g., construction) than those from wealthy backgrounds (e.g., Clougherty *et al.*, 2010;

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[b)]Email: nairan.ramirez@uconn.edu

Flamme *et al.*, 2012). As a result, minority groups are at increased risk of developing noise-related hearing loss as well as psychological conditions related to loud environments (Basner *et al.*, 2014; Arnold *et al.*, 2023). Cultural behaviors might also contribute to differences in acoustic environments. Some cultures, such as Latin American cultures, are known to be collectivistic, where an interdependent self is socially promoted. That is, individuals tend to care about and value interacting and integrating with others (Markus and Kitayama, 1991; Pelham *et al.*, 2022; Ramírez-Esparza *et al.*, 2012). This contrasts with individualistic cultures (e.g., individuals who identify as white and have a European heritage), in which the independent self is at the center of the individual's social development and people tend to prioritize individual goals, needs, and rights above those of the collective (Markus and Kitayama, 1991; Pelham *et al.*, 2022; Ramírez-Esparza *et al.*, 2012). This tendency for collectivism versus individualism manifests in cultural norms and behaviors. For example, Latinx students living in the U.S., in accordance with their collectivistic values, spend more time socializing with others and in group interactions than students from European backgrounds (Ramírez-Esparza *et al.*, 2009; Ramírez-Esparza *et al.*, 2012). This behavioral collectivism might lead to noisier acoustic environments.

Our work suggests, based on empirical data, that cultural dynamics might shape acoustic environments independent of socioeconomic pressures (Benítez-Barrera *et al.*, 2023). Unlike previous studies that had used geographic area monitoring (i.e., sound level meters located in different neighborhoods) to extract environmental noise levels, Benítez-Barrera *et al.* (2023) used body-worn sound recorders to measure personal acoustic environments. As a result, they were able to go beyond capturing overall neighborhood environmental sound levels produced by mechanized sources (e.g., noise from roads, railways, air traffic, and industrial construction) to focus on measuring a person's nearfield noise levels during social dynamics (e.g., interpersonal communication). Nearfield was defined as the immediate environment surrounding the listener that is "earshot" of the body-worn recorder. In this and our previous studies, nearfield noise measurements represent sound levels continuously measured in the listener's proximity. Using this novel approach, Benítez-Barrera and colleagues found that students from Latinx heritage experience higher nearfield noise levels than college students from European heritage. In addition, the nearfield noise levels experienced by both groups did not exceed the dB levels that, if sustained over time, would likely result in hearing loss (e.g., Daniel, 2007). Thus, noise levels related to cultural dynamics are not necessarily problematic for an individual's hearing health.

The Benítez-Barrera *et al.* (2023) study compared sound levels between cultures and did not analyze social variables, such as behavioral collectivism, that could influence nearfield noise levels. In our dataset, students of Latinx heritage came from lower-SES backgrounds than students of European heritage. Thus, potential differences in behavioral collectivism and nearfield noise levels across groups could potentially be attributed to SES instead of culture (Miyamoto *et al.*, 2018). The goal of the current study, therefore, was to expand on this previous research by examining whether behavioral collectivism is associated with nearfield noise levels. Additionally, the current study sought to determine whether culture and/or SES was a mediating factor in this relationship. By investigating the relationship between behavioral collectivism, cultural heritage, and SES in the context of nearfield noise levels, we aimed to elucidate the complexity of factors shaping an individual's acoustic environment.

A. Study overview

In the U.S., individualistic values are often associated with individuals who self-identify as white, have European heritage, and speak English as their native language. Conversely, collectivistic values have been primarily, though not exclusively, associated with individuals who self-identify as having Latin American heritage and speak Spanish as their native language. Thus, to study the effects of individualistic versus collectivistic values on acoustic environments, we compared college students of European and Latinx heritages, respectively.

Students wore a Language ENvironment Analysis (LENA^{TM}; Oller *et al.*, 2010) digital recorder as they went about their daily lives. The recordings were first analyzed with a novel algorithm to calculate nearfield noise levels (Benítez-Barrera *et al.*, 2023). Then, the same recordings were used to manually code and assess behavioral collectivism. The research questions for the study were threefold. (1) Is behavioral collectivism associated with higher nearfield noise levels? (2) Does behavioral collectivism mediate the association between cultural heritage and nearfield noise levels? (3) Does behavioral collectivism mediate the association between SES and nearfield noise levels? To answer these questions, first, we performed correlational analyses to test whether behavioral collectivism relates to nearfield noise levels across both groups. Then, we conducted two mediation analyses to test the models depicted in Figs. 1(A) and 1(B). Panels (A) (Model 1) and (B) (Model 2) depict cultural heritage and SES as predictors of nearfield noise levels, respectively. Behavioral collectivism served as the mediator in both models. Because the study expanded on earlier findings and was not originally designed to address these specific research questions in this dataset, the aims and analyses were exploratory in nature. As a result, no specific *a priori* hypotheses were established.

II. METHOD

This research project received approval from the Institutional Review Board (IRB) at the University of Connecticut, Storrs. The IRB approval ensures that the research was conducted in accordance with ethical guidelines and standards for the protection of human subjects, including obtaining informed consent.

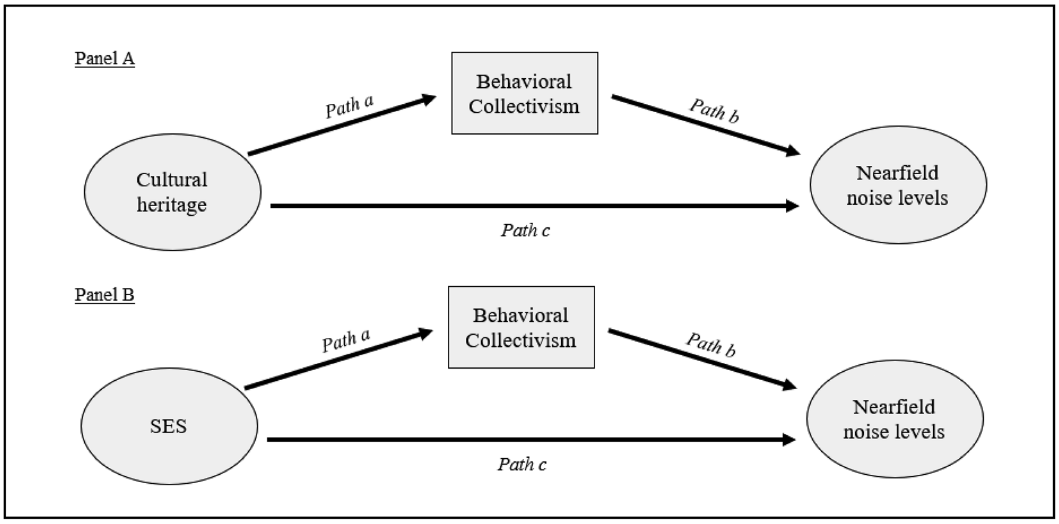

FIG. 1. Path diagrams illustrating the two models. In panel (A), behavioral collectivism mediates the association between cultural heritage (i.e., Latinx vs. European heritage) and nearfield noise levels (Model 1). In panel (B), behavioral collectivism mediates the association between SES and nearfield noise levels (Model 2).

A. Participants

A total of 74 participants took part in a large-scale study at the University of Connecticut to assess how daily language use and social interactions relate to brain measures of speech perception. Portions of these data have been published elsewhere (e.g., Benítez-Barrera *et al.*, 2023; Skoe *et al.*, 2022). Thirty-one participants were of Latinx heritage [23 women, mean age = 20.17 years, standard deviation (SD) = 1.48], and 43 were of European heritage (34 women, mean age = 20.28, SD = 1.37).

1. Students' cultural and language characteristics

a. Students of Latinx heritage. Students reported that, on average, they had been living in the U.S. for 16.36 years (SD = 5.63), with 20 living in the U.S. since birth. Cultural heritage represented different parts of Latin America: nine students from Mexico, four from the Dominican Republic, four from Ecuador, three from Peru, two from Colombia, two from Guatemala, one from Argentina, one from Bolivia, one from Costa Rica, one from Cuba, one from El Salvador, and one from Puerto Rico. (One student did not respond.) All students indicated being Spanish-English bilingual. On a Likert scale of 1 = "I cannot speak the language fluently" to 5 = "I have native-like proficiency," participants' averages were 4.95 (SD = 0.25) for English and 4.57 (SD = 0.63) for Spanish.

b. Students of European heritage. All students reported that they were born in the U.S. Forty-two students said that they had a European heritage. (One student did not respond.) All students indicated being white and English monolingual speakers.

2. SES

Participants were asked to indicate the SES of the person or people who raised them on a Likert scale: 1 = working class, 2 = lower-middle class, 3 = middle class, 4 = upper-middle class, and 5 = upper class. The number of students of Latinx heritage (mean = 2.19, SD = 1.08) was lower than that of students of European heritage (mean = 3.49, SD = 0.80) [$t(72) = 5.94$, $p < 0.001$, Cohen's $d = -1.4$, 95% confidence interval (CI) = –1.9, –0.88].

B. LENA sound recordings

LENA is a platform of hardware and software that can record and analyze the acoustic and linguistic characteristics of participants' environments as they go about their daily activities (e.g., Oller *et al.*, 2010; Ferjan Ramírez *et al.*, 2023; Ramírez-Esparza and García-Sierra, 2014; Ramírez-Esparza *et al.*, 2017a,b; Romeo *et al.*, 2018; Wu *et al.*, 2018). The LENA body-worn recorder can reliably capture nearfield speech and other sounds that occur approximately 6–8 ft away from the recorder wearer. In the current study, participants were provided with two recorders [LENA digital language processors (DLPs)] and an armband to carry them. Each recorder has the capacity to store up to 16 h of continuous audio. Participants were instructed to wear the recorders and have them on for at least 8 h and record continuously (with the option of turning them off if needed and recording for more hours if wanted) for one weekday and one weekend day of their choice. Recordings were used to calculate nearfield noise levels and code for social behaviors. Students were also required to record their activities in a daily activity diary (e.g., woke up, drove to campus, attended class, ate with companions, etc.) that was used to aid social behavior coding.

C. Behavioral coding

We used LENA recordings to manually code for and assess social collectivism.

1. LENA data preparation

In preparation for behavioral coding, the audio files for each participant were processed using the LENA ADVANCED DATA EXTRACTOR (ADEX) tool. This tool was used to extract speech intervals for behavioral coding. A different procedure was used to extract speech intervals for capturing nearfield noise level measurements. In other words, the speech intervals used for behavioral coding are not necessarily the same as those used for acoustic analysis, although there is likely some partial overlap. ADEX provides outputs for the LENA speech intervals as short as a fraction of a second and automatically calculates the adult word count. The outputs are aggregated at 30-s intervals, a technique that ensures minimal personal information is captured while still providing sufficient data for reliable coding. This approach has been extensively used in prior research (e.g., Mehl *et al.*, 2007; Orena *et al.*, 2020; Ramírez-Esparza *et al.*, 2009, Ramírez-Esparza and García-Sierra, 2014; Ramírez-Esparza *et al.*, 2017a,b). We then selected intervals for coding by removing those with zero adult words. From the remaining intervals, we chose about 70 intervals per day with the highest word count for behavioral coding. Previous research has shown that 70 intervals are representative of a full day recording (Mehl *et al.*, 2007; Ramírez-Esparza *et al.*, 2012). Notably, no significant differences were observed between the average word counts within selected intervals across groups [Latinx, mean = 91.35, SD = 50.64; European backgrounds, mean = 71.57, SD = 34.86; $t = 1.77$, $p = 0.08$]. Thus, we were able to code behavioral collectivistic tendencies across groups with similar social dynamics. Therefore, ideally, the final data set to analyze would include a total of 140 30-s intervals for each participant per day; however, some participants did not have 140 eligible intervals (e.g., participants did not follow instructions, or there was excessive silence and no language activity). On average, 121.68 (SD = 24.92; minimum = 70 and maximum = 140) and 118.44 (SD = 30.13; minimum = 39 and maximum = 140) intervals were coded for students of Latinx heritage and European heritage, respectively. Importantly, the average numbers of coded intervals did not differ significantly across groups ($t = -0.49$, $p = 0.63$).

2. Coding procedure

Nine coders (six Spanish-English bilinguals and three English monolinguals) listened to and coded each of the 30-s intervals according to an adapted version of the Social Environment Coding of Sound Inventory (SECSI; e.g., Ramírez-Esparza *et al.*, 2019). The SECSI includes 62 categories. Categories are non-exhaustive and non-mutually exclusive, so more than one category can be selected for a given behavior (e.g., for a given behavior, coders can indicate that the student is "not alone," is with a "group of people," and is "socializing"). Coders were provided with basic information about each interval (date, day of the week, time of day, and the time stamp of the audio recording) and were given the participants' diaries to facilitate coding. The transcription software played a specific 30-s interval for coding based on the time stamp entered. The coders listened to each 30-s interval and then coded each category associated with it. In each 30-s interval, the coders entered "YES" if the behavioral category of interest occurred (i.e., if the participant was alone, the coders indicated "YES" on the category alone; if the participant was with a group of people, the coders indicated "YES" on the category "group interaction"). The data were then converted into proportion of time estimates by calculating the percentage of intervals that were included in a specific subcategory across all coded intervals (e.g., the percentage of intervals in which the participant was alone across the two days coded). For example, a proportion of time estimate of 25% for the SECSI category "alone" indicated that for a participant with 140 intervals, this category was coded as "YES" in 35 of the 140 coded intervals for that participant.

Our assumption was that collectivistic behaviors are associated with increased nearfield noise levels in day-to-day acoustic environments. Thus, our goal was to operationalize this construct from the participant's audio recordings by identifying the various ways individuals demonstrate collectivism in their everyday social behaviors. To achieve this goal, we used the collectivism-individualism framework proposed in previous studies (Ramírez-Esparza *et al.*, 2009; Ramírez-Esparza *et al.*, 2012). Specifically, we chose three social behavior categories from the SECSI that capture the essence of collectivism as feelings of integration with others. The first step was to determine the extent to which participants spent time with others during periods of high language input. Note that it is possible that some of those intervals included instances where the participant was alone (participant is doing homework in a cafeteria or talking to a pet). Then intervals identified as "with others" were further analyzed to determine whether the participants were socializing with a group of people and whether they were actively engaged with other people in the group. These are parameters previously identified with collectivistic behaviors (Markus and Kitayama, 1991; Pelham *et al.*, 2022; Ramírez-Esparza *et al.*, 2009; Ramírez-Esparza *et al.*, 2012). In summary, we used the audio recordings to measure (1) the proportion of time students spent with others (reverse coding of category "alone"), (2) the proportion of time they spent interacting in groups (i.e., the participant is with two or more people), and (3) the proportion of time they spent socializing (i.e., defined as a non-instrumental social activity with the main purpose of "hanging out" with others or to simply enjoy the company of others). We considered these three categories because each of them represents a different component of behavioral collectivism. For instance, being with others exhibits collectivistic behavior; however, a student might be in a group of people (not by themselves), but not necessarily interacting with them. For example, if they were studying at a coffee shop, this would have received a score of 1 for the category "with others" and a score of 0 for the categories "in groups" and "socializing." Similarly, someone might be participating in a group activity, but with no direct interaction; this would have received a score of 1 for the categories "with others" and "in groups" and 0 for the category "socializing." Therefore, the three SECSI components of collectivistic behaviors define behavioral collectivism holistically. To examine the potential interrelationships between these variables, we conducted a principal component analysis. Results showed that, indeed, these three variables load into a single factor, explaining 75.54% and 68.85% of the variance of behavioral collectivism for students of Latinx heritage and European heritage, respectively. Thus, we computed a composite measure of behavioral collectivism (the behavioral collectivism score) by adding the three categories and dividing the sum by 3.

Table I depicts means and SDs for each of the SECSI categories, as well as the behavioral collectivism score. Coders were blind to the procedures of this study. Inter-coder reliability was determined from a set of training intervals selected from a participant of European heritage (100 total). Table I shows that the three categories used in the analysis produced an average intra-class correlation (ICC) of 0.82—indicating effective training and reliable coding—based on a two-way random effects model [ICC(2, *k*)] (Shrout and Fleiss, 1979).

D. Nearfield noise levels measurement from the LENA recordings

It should be noted that to calculate nearfield noise levels, we used a different approach to the behavioral coding scheme described in Sec. II C, which used 30-s speech intervals with the highest word counts, and thus, represents a small portion of the recording (∼60–70 min total per day). Nearfield noise levels, in contrast, were calculated using LENA's automatic algorithms from the entire recording. Thus, for a recording of 8 h duration, the full 8-h period was used to estimate the nearfield noise levels for that day.

Benítez-Barrera *et al.* (2020) described an algorithm for calculating nearfield noise levels that was applied here. This algorithm partially relies on automated analyses performed by LENA software to estimate nearfield noise levels, along with speech levels, and speech-to noise (SNRs) (not reported here). Briefly, LENA classifies the sound recordings automatically into segments that it labels as speech (female, male, and children), noise, overlap, TV/electronics, and silence. These brief segments, which range in length from 0.5 to 5 s, are the smallest unit of analysis that the LENA software offers. The system further labels these segments as "near" or "far" based on their estimated proximity to the recording device as well as on how well *a priori* statistical model for each category fits for that segment (see Xu *et al.*, 2009). Near segments are those where the software estimates the sound was generated within 6 to 8 ft from the recorder, while far segments are estimated to be generated more than 6 to 8 ft away. Importantly, the software provides an estimation of the sound level in dBc for each labeled sound.

The software then produces a comprehensive summary of each recording day, complete with time-stamped labels for each identified segment (e.g., female speech near, noise near). Then, it divides the recordings into conversation and pause blocks. Conversation blocks include sections with "near" speech segments interspersed with either non-speech (noise, TV/electronics, or silence), overlap (i.e., two people talking simultaneously), or "far" speech segments. Conversely, pause blocks are sections that lack "near" speech segments, containing only non-speech, overlapping speech, and "far" speech categories. A pause block is defined as a section lasting more than 5 s without any near human speech. A pause block follows every conversation block to form pairs of conversation-pause blocks.

The algorithm described by Benítez-Barrera *et al.* (2020) uses sound levels from noise, TV/electronics, and silence labels to calculate a time-weighted power average nearfield noise level for each conversation-pause block pair. These levels are averaged in a time-weighted manner to determine the average nearfield noise level across all conversation-pause blocks for a given recording day. Finally, the noise levels from the two recording days are averaged to produce a two-day average noise level. For detailed information about the algorithm, refer to Benítez-Barrera *et al.* (2020). Of note, the nearfield noise level data for this dataset was published in Benítez-Barrera *et al.* (2023). This earlier work reported that the average nearfield noise levels for the students of Latinx heritage (mean = 64.8 dBc, SD = 3.4) were significantly higher than for the students of European heritage (mean = 63.0 dBc, SD = 4.0) [$t(69.6) = 2.1$, $p = 0.04$, 95% CI = 0.06, 3.5].

TABLE I. Descriptive statistics and reliabilities of behavioral variables.[a]

Behavioral category	ICC	Proportion of time for students of: Latinx heritage ($n = 31$) Mean	SD	European heritage ($n = 43$) Mean	SD	Statistics[b] *t* value (independent)	Effect size (Cohen's *d*)
Behavioral collectivism	—[c]	63.18	19.70	53.03	18.16	2.29*	0.54 (0.07, 1.00)
With others	0.89	79.52	20.23	72.72	20.48	1.42	0.33 (−0.13, 0.80)
Group social interactions	0.90	47.55	25.86	34.42	21.24	2.39*	0.56 (0.09, 1.03)
Socializing	0.67	62.48	21.97	51.95	24.23	1.92^	0.45 (−0.02, 0.92)

[a]Intercoder reliabilities were computed as intra-class correlations [ICC(2, *k*)] from a training set of 100 intervals that were independently coded by nine coders.
[b]^, $p = 0.06$; *, $p < 0.05$.
[c]No reliability is reported because the variable is an average of three coded variables (i.e., with others, group social interactions, and socializing).

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TABLE II. Correlations among the variables of interest in this study across groups.[a]

	Correlation across groups[b]		
Variable of interest ($n = 74$)	1	2	3
1. Cultural heritage	1.00		
2. Socioeconomic status	−0.57***	1.00	
3. Behavioral collectivism	0.26*	−0.16	1.00
4. Nearfield noise levels	0.23*	−0.27*	0.34**

[a]Cultural heritage was dummy coded.
[b]*, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

E. Statistical analyses

To test whether the composite measure of behavioral collectivism is associated with nearfield noise levels (Research Question 1), we computed bivariate correlations between these two variables and between behavioral collectivism, cultural heritage, and SES. Following mediation analysis practices, we only conducted mediation analyses if behavioral collectivism was associated with each of the predictors (cultural heritage and SES) and the outcome measure (nearfield noise levels). Two mediation models were tested (Fig. 1). Specifically, to explore whether behavioral collectivism mediated the relationship between cultural heritage and nearfield noise levels (Model 1, Research Question 2) and between SES and nearfield noise levels (Model 2, Research Question 3), we conducted two mediation analyses. In these models, cultural heritage and SES were considered independent predictors, while nearfield noise levels were inputted as the outcome variable. In Model 1, cultural heritage was converted to a dummy coded variable where students of Latinx heritage received a score of 1 and students of European heritage received a score of 0. Thus, positive scores indicate a correlation in the direction of students of Latinx heritage. Bootstrapping was used to test mediation with 5000 samples to make a 95% CI for the indirect effect through the process macro (Hayes, 2022). All test results reported herein reflect two-tailed values. Thresholds for significance levels were established at $p < 0.05$.

III. RESULTS

Participants averaged 23.3 audio recording hours (SD = 6.1) across both days. A Welch two-sample t test showed no significant differences in the total number of recording hours across groups [$t(71.9) = -0.2$, $p = 0.9$, 95% CI, −10 838.2, 9074.9)]. Moreover, a paired sample t test showed that participants were recorded, on average, for the same number of hours each day, independently of group [day 1, mean = 11.9, SD = 2.7; day 2, mean = 11.9, SD = 3.10; $t(71) = -0.13$, $p = 0.9$, 95% CI, −2670.9, 2339.9]. Finally, coders reported that someone was talking (either the participant or someone else) in 81% (SD = 14.4%) of the chosen intervals for students from Latinx backgrounds and 82% (SD = 13.5%) of the chosen intervals for students from European backgrounds [$t(72) = 0.38$, $p = 0.69$). This indicates that social interaction occurred in the majority of the selected intervals based on the highest word count provided by the LENA software.

Regarding the relationship between behavioral collectivism and nearfield noise levels (Research Question 1), we found that these variables were positively associated ($r = 0.34$, $p < 0.01$). (Table II shows the bivariate correlations between variables across groups.) Only Model 1 could be tested because cultural heritage was significantly associated with behavioral collectivism (i.e., Research Question 2, Model 1, $r = 0.26$, $p < 0.05$) (also see Table I for means across groups), while SES was not associated with behavioral collectivism (model 2, $r = -0.16$, $p = 0.17$). This is shown in Table II.

Thus, for Model 1, Fig. 2 shows that there was a positive and significant relationship between cultural heritage and nearfield noise levels (path c, $b = 1.79$, $p < 0.05$). Furthermore, the theorized mediation by behavioral collectivism was also found to be significant. Specifically, results show that there was a positive and significant relationship between cultural heritage and behavioral collectivism ($b = 10.15$, $p < 0.05$) and a positive and significant relationship between behavioral collectivism and nearfield noise levels ($b = 0.06$, $p < 0.05$). In addition, the relationship between cultural heritage and nearfield noise levels was reduced in magnitude and no longer significant when behavioral collectivism was included in the model (i.e., from 1.79, $p < 0.05$, to 1.19, $p = 0.18$). Behavioral collectivism was deemed a significant mediator because the 95% bias-corrected CI based on 5000 bootstrap samples indicated that the indirect effect through behavioral collectivism (Path ab = 0.60) was entirely above zero (0.05 to 1.48). The theorized mediation model, including cultural heritage and behavioral collectivism, accounted for 5.35% of the variance in nearfield noise levels: $F(1, 72) = 4.07$, $p < 0.05$.

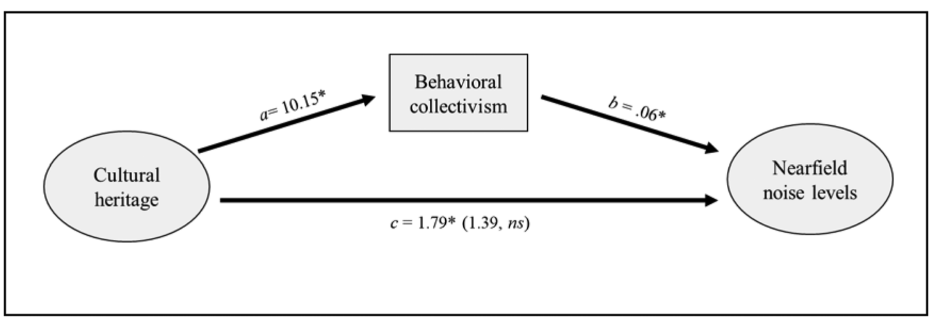

FIG. 2. Mediation analyses: Behavioral collectivism mediates the relationship between cultural heritage and nearfield noise levels. Cultural heritage was dummy coded, where students of Latinx heritage were given a score of 1 and students of European heritage a score of 0. Positive scores indicate a relationship in favor of Latinx. *, $p < 0.05$; ns, no significance.

IV. DISCUSSION

In her 2022 essay, Xochitl Gonzalez reflects on her experience with noisy environments and how these could be associated with wealth while also being deeply connected with her cultural heritage. This perspective is consistent with what has been acknowledged before in the literature that culture and SES are tightly intertwined in the U.S., to the point that it is not always feasible to separate one from the other (e.g., Kawachi *et al.*, 2005). Building on our previous work showing that college students of Latinx heritage tend to experience higher levels of nearfield noise than their peers of European heritage (Benítez-Barrera *et al.*, 2023), the present study aimed to understand whether those findings could be explained by social behaviors differentiating the groups. Our research questions were as follows: (1) Is behavioral collectivism associated with nearfield noise levels across groups? (2) Does behavioral collectivism mediate the association between cultural heritage and nearfield noise levels? (3) Does behavioral collectivism mediate the association between SES and nearfield noise levels? We found that collectivistic behaviors were positively associated with nearfield noise levels and that such behaviors mediated the relationship between cultural heritage and nearfield noise levels. Further, the relationship between SES and behavioral collectivism was not significant. These findings suggest that students of Latinx heritage might experience noisier environments than students of European heritage because, according to their cultural values, they engage in more collectivistic behaviors than their peers during their daily lives. This investigation expands our understanding of how cultural dynamics influence acoustic environments, and it offers new insights into the potential relationship between environment and health outcomes in diverse communities.

Our study revealed that noisy environments might be characterized, at least partly, by individuals spending time with others and socializing. Although our analyses do not allow us to establish a causal relationship, it is reasonable to suggest that regardless of cultural and socioeconomic background, individuals who spend more time with others are more likely to experience noisier acoustic environments than those with individualistic preferences. Notably, our nearfield noise estimates did not include masking speech, even though this type of masking could be significant in crowded social settings. Thus, because the noise estimates are based on non-speech segments, the nearfield noise levels in the Latinx heritage group compared to the European heritage group are not solely a result of other people talking. Instead, we capture ambient noise levels that tend to be elevated in social environments due to factors such as crowded conditions, music, and the acoustic properties of the spaces. It is also important to note that the noise levels experienced by participants in the present study were less than 65 dBc on average and did not exceed limits that could potentially lead to increases in the risk of noise-induced hearing loss (Hong *et al.*, 2013; Sliwinska-Kowalska and Davis, 2012). Thus, risks for hearing-related problems in socially active individuals in our dataset are unlikely unless the social activity itself involves high intensity sound (e.g., being in the college marching band; Skoe and Tufts, 2018). That said, even if daily sound levels are not harmful to hearing, noisy environments could potentially lead to higher levels of stress, ultimately affecting individuals' psychological well-being (Bragdon, 2016; Sjödin *et al.*, 2012; Yazdanirad *et al.*, 2023).

Collectivistic behaviors did not correlate with SES. This aligns with a previous study that showed no relationship between SES and the propensity to emphasize and promote relationships with others in the U.S. (Miyamoto *et al.*, 2018). Although additional research is needed to confirm these findings, we suggest that although culture and SES are often intertwined in the U.S., they are independent constructs as they relate to collectivism and nearfield noise levels. We speculate that SES impacts environmental noise levels based on where people live and work, whereas cultural values affect nearfield noise levels as they relate to cultural dynamics, including collectivistic behaviors. Notably, our participants, regardless of their SES background, were part of the same university campus; thus, environmental noise levels (i.e., noise pollution) were likely not substantially different across participants in this study. Therefore, differences in nearfield noise levels across groups are likely, at least in part, to be explained by cultural values. This, combined with the fact that the noise levels experienced by our participants were not high enough to be damaging to their hearing, opens the possibility that a higher incidence of hearing-related health problems in minority populations is related to SES rather than culture (Nieman *et al.*, 2016). That is, in minority populations, regardless of cultural preferences for noise, increased risk of hearing loss is likely associated with SES-determined environmental conditions and not cultural factors. The fact that people of European heritage from low-SES backgrounds experience noise-induced hearing loss at a higher rate than their high-SES counterparts lends support to this possibility (Casey *et al.*, 2017). Future hypothesis-driven research should confirm these speculations.

In sum, our mediation models revealed that collectivistic behaviors mediated the relationship between cultural heritage and nearfield noise levels. This provides support for previous findings in which Latinx individuals expressed their interdependent selves by spending time with others and socializing (Markus and Kitayama, 1991; Pelham *et al.*, 2022; Ramírez-Esparza *et al.*, 2012). More importantly, we confirmed that these collectivistic behaviors relate to the higher nearfield noise levels experienced by students of Latinx heritage when compared to students of European heritage. This is the first evidence supporting the possibility that cultural dynamics shape acoustic environments. Whether this leads to differences in health outcomes between cultural groups remains unknown.

A. Other future directions

Previous research has shown that environmental sounds could be classified as noise in certain situations (e.g., Guastavino, 2007). However, based on personal experiences, what one person hears as noise could be heard as meaningful sound by another (Kang and Schulte-Fortkamp, 2016). Individuals from cultures that engage more with noise and/or have higher levels of noise input might attach greater meaning to those sounds compared to those who experience quieter environments (Kang and Schulte-Fortkamp, 2016). This attachment to meaning could lead these people to seek out and develop tolerance for these environments in their daily lives (Henry *et al.*, 2022; Weinstein, 1978). Moreover, the well-known psychological benefits of a socially active life might outweigh the potential stress-related consequences. In fact, individuals engaging in social group activities rate the acoustic environment as more pleasant and less chaotic (Tarlao *et al.*, 2021). Thus, despite the increased noise levels, for some individuals, especially those who consider collectivism culturally salient, spending time in a bustling restaurant and engaging with others might provide a sense of belonging, satisfaction, and meaningfulness, positively impacting their well-being and health (e.g., Holt-Lunstad *et al.*, 2010).

It should be noted that Benítez-Barrera *et al.* (2023) found that speech levels did not differ between cultural groups, but noise levels did (higher for students of Latinx heritage than European heritage). The difference in noise levels was <2 dB, which is small on its face but still expected to be perceptibly different (Moore and Raab, 1975; Schneider and Parker, 1987). This difference leads to lower SNRs during communication exchanges in the Latinx group than in the European group (Benítez-Barrera *et al.*, 2023). That is, the speech signal is likely less acoustically salient for Latinx students than those from European backgrounds during communication exchanges, potentially limiting their ability to acoustically access speech input of interest. Specifically, speech intelligibility is expected to decrease by 12% with a 2 dB difference in SNR, which is a clinically meaningful drop (MacPherson and Akeroyd, 2014). In addition, research has shown that low SNRs increase listening effort and fatigue (e.g., Rennies *et al.*, 2014). In low SNRs, it is thought that listeners need to devote more cognitive resources to accessing speech input, which leads to feelings of tiredness and mental fatigue. Importantly, self-reported listening fatigue is known to negatively impact academic and occupational performance (McGarrigle *et al.*, 2014; Visentin *et al.*, 2023). Thus, low SNRs could affect the quality of life for Latinx individuals. However, we note that the influence of culture has not been given significant attention in the literature on listening fatigue (or intensity discrimination, for that matter), so we leave open the possibility that (1) there are cultural differences in listening fatigue and (2) that more experience with noise is associated with lower fatigue. For instance, socially active individuals might have more opportunities to practice listening in noise, which could strengthen their listening skills and lead to an increased tolerance to low SNRs. The fact that the additional background noise present in their environment was not associated with a commensurate increase in the sound level of nearfield speech might indicate that the Latinx students are more tolerant of noise than their European peers. That is, Latinx may not perceive a perceptual deficit when listening in noisy environments, which might indicate that they are comfortable in those settings. Nevertheless, increased nearfield noise levels experienced by socially active individuals may or may not affect health outcomes. This warrants further investigation using perceptual tests of speech perception in noise and background noise tolerance (cf. Camera *et al.*, 2019).

Interestingly, personality traits are also associated with the acoustic environment. For example, extroverted individuals show more tolerance to noise, perceiving noisy activities such as shopping, recreation, and group activities as more pleasant than their introverted counterparts (Tarlao *et al.*, 2021; Steffens *et al.*, 2017). Personality profiles of cultures have been proposed by analyzing the mean trait levels of culture members (e.g., McCrae and Terracciano, 2005). Therefore, it is possible that extroverted individuals in the European heritage group experience levels of nearfield noise similar to the Latinx and vice versa. To make the results more powerful and applicable to a wider range of people, future research could use bigger and more varied samples and look at personality traits, age groups, and/or cultural groups. This would also increase the amount of variation that can be explained by nearfield noise levels.

B. Limitations

This study is not without limitations. First, the study design limits our ability to draw causal conclusions about the relationships observed. Longitudinal studies could provide more insight into how cultural dynamics and social behaviors evolve over time and interact with noisy environments. Second, our sample consists of a relatively small group of college students, primarily women, from a specific university. Interestingly, women have been shown to occupy the public space more in groups than men (Franck and Paxson, 1989; Tarlao *et al.*, 2021). Thus, our sample might not be fully representative of broader populations. In addition, our sample size might have prevented us from having sufficient power to detect additional relationships between our variables in the models.

Third, there are significant limitations to the characterization of individualistic and collectivistic groups. We solely compared two distinct cultures without considering potential variations within the cultural groups or other cultural factors that could influence the results. Given the diverse origins of the students from various regions of Latin America, we were unable to pinpoint our findings to a particular cultural subgroup. Furthermore, we were unable to determine the specific European heritage (Northern vs Southern Europe) of our European heritage group. Although we found differences between students of Latinx heritage and European heritage, it is possible that differences might exist within the European heritage group regarding their collectivistic tendencies, depending on their specific European origin and how recently their family immigrated to the U.S. Importantly, our approach only considers values related to the individualism-collectivism framework and ignores other cultural factors (such as religion and norms) that might also be related to acoustic environments. Since we did not include questionnaires to directly assess collectivistic and individualistic traits in our participants, our approach limited our ability to factor in each person's personality and the value they place on collectivistic behavior. Combining coded behaviors with questionnaires would allow for a more complete picture of participants' psychological and cultural profiles.

Last, our study did not measure participants' speech-in-noise skills or their tolerance for noise. This limitation limits our ability to fully comprehend how people from various backgrounds might handle or react to various acoustic environments. Future research could delve into these aspects to gain a more comprehensive perspective on the relationship between culture, social behaviors, and acoustic environments.

C. Concluding remarks

Our findings shed light on the interplay between culture and acoustic environments. The long-term goal of this line of research is to provide information to guide interventions and policies that promote healthy auditory experiences for everyone, acknowledge that acoustic environments are diverse across cultures, and lead to a greater appreciation for cultural differences in what is considered "noise." This idea is nicely expressed by Gonzalez, who writes: "I had taken the sounds of home for granted. My grandmother's bellows from across the apartment, my friends screaming my name from the street below my window. The garbage trucks, the car alarms, the fireworks set off nowhere near the Fourth of July. The music. I had thought these were the sounds of poverty of being trapped. I realized, in their absence, that they were the sounds of my identity, turned up to 11."

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AUTHOR DECLARATIONS
Conflict of Interest

The authors have no conflicts to disclose.

Ethics Approval

This research project received approval from the Institutional Review Board (IRB) at the University of Connecticut, Storrs. The IRB approval ensures that the research was conducted in accordance with ethical guidelines and standards for the protection of human subjects, including obtaining informed consent.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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