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Investigating cross-cultural emotional responses to world music under simulated hearing loss

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SUMMARY

In today's dynamic and interconnected world, emotional response to music is an experience that connects people across cultures. Regardless of cultural background, the music listening experience is impeded for people facing hearing loss. Hearing loss is quite prevalent, yet little is known about how those with impaired hearing experience emotions in response to music. This project's objective was to understand cross-cultural emotional responses to music and how they are altered under hearing-impaired conditions. We studied emotions expressed by people from two different countries after listening to world music and investigated how these emotions varied under simulated hearing loss. We first hypothesized that emotions elicited by music would be similar across people from the U.S. and India. We next hypothesized that emotions found to be elicited similarly across cultures would continue to be experienced when listening to music under simulated hearing loss conditions. In this study, we surveyed 984 participants from the two countries, asking them to identify the emotions elicited by 100 world music clips. We then repeated the survey with an additional 886 participants using clips in which the music was modified to simulate hearing loss. Our results indicated that, of the 20 emotions studied, 8 were prominently positively correlated across both countries. Furthermore, we found that these emotions differed from the emotions correlated across the two countries under simulated hearing loss, potentially providing new insight into how hearing loss affects emotional perceptions of music. The conclusions have implications in audiology, psychology, and for the music industry as it relates to hearing loss.

INTRODUCTION

We live in an increasingly dynamic world. Technology has connected people like never before, and immigration has brought diverse cultures together. Today's diverse society can benefit from a better scientific understanding of how human beings across cultures experience intense emotions. Poets and philosophers have long described music as a universal language of humankind, but little is known about this often-quoted claim (1). This universal nature of music is generally acknowledged but not tangibly demonstrated. Emotions can be exceedingly complex and nuanced, and a richer taxonomy of emotions is often needed to capture the variability of emotional response (2). Understanding the common basis of feelings and emotions in reaction to music may be one way to demonstrate the universal nature of music.

Music is considered to be part of human biology (3). Human evolution and social organization – for example, the formation of cooperative relationships between groups of human beings – is closely tied to music in the form of storytelling, rituals, and signaling (4). Similarly, infant-directed songs arose out of the evolution of parent-offspring relationships (5). These phenomena are widespread across cultures (5–7). However, expert opinion has often countered claims of music being universal (8, 9). Studies have pointed to how a single piece of music is subject to a variety of interpretations and how difficult it is to systematically compare music across societies (10, 11).

Music perception is closely tied to one's hearing abilities. Hearing is one of our most important senses, and one researcher made the argument that hearing is the swiftest of emotional triggers and influences the mind deeply (12). The World Health Organization reports that 430 million people worldwide experience disabling levels of hearing loss, and this number is projected to grow to over 700 million by 2050 (13). Hearing loss can have a major impact on an individual's quality of life, including their physical, cognitive and mental health (14, 15). There is also evidence of a correlation between hearing loss and depressive symptoms (15, 16). Music is heard very differently by individuals with hearing loss. Many adults who use cochlear implants or hearing aids have difficulty listening to music (17). However, an inability to hear music does not translate to an inability to feel emotions while experiencing music. Beethoven composed his greatest music when he was profoundly deaf (18). People with profound hearing loss can still experience music through the auditory cortex, similar to people with normal hearing (19). Thus, people with hearing loss may continue to enjoy music, owing to the flexibility and adaptability of the brain.

Recent studies have taken important steps in the direction of comparing reactions to music across societies (20, 21). In a 2019 study conducted by Mehr, et al., the authors methodically analyzed the features of vocal music on a worldwide basis (20). The authors sought to demonstrate the universality of music using surveys, where participants categorized clips of songs carefully curated from ethnic cultures across the world. The results demonstrated a high statistical correlation between the correct categorization of the song and what the surveyors chose. In another study by Cowen, et al. in 2020, the authors attempted to organize subjective experiences associated with music in the form of emotions across two different countries: the U.S. and China (21). They asked two groups of participants (American and Chinese) to listen to samples of Western and Chinese instrumental music and collected data on specific feelings associated with the music.

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They uncovered that several feelings elicited in reaction to the music clips were correlated between both the countries studied.

These studies stop short of providing a consolidated view on the reaction to music across societies, partly due to the complexities involved (20, 21). The study by Mehr, et al. did not include emotive and subjective judgments of the participants (20). In the Cowen, et al. study, the music used was purely instrumental in nature, limiting the ability to draw upon the richer subjective experiences that human sounds generate (21). Neither study explored reactions to music under hearing-impaired conditions.

How the emotions experienced by people with hearing loss compare to the emotions experienced by people with regular hearing is a topic with unclear conclusions. In a review study conducted by Picou, et al. in 2018, the authors examined prior research on how hearing loss impacts emotions (22). In a study conducted by Chatterjee, et al., the authors discuss significant deficits in voice emotion recognition for hearing-impaired people relative to people with normal hearing but suggest that cochlear implants could bridge the gap (23). Another study suggests that timbre perception in music is significantly altered for people with hearing loss, impacting their ability to perceive emotions (24). The inability to draw clear conclusions can be attributed to variability across studies, as well as the complexity involved in measuring perception.

Considering the connections between hearing and emotions, a hearing loss environment represents a fertile testing ground to examine the resilience of emotions. This study's objective was to understand how emotions elicited by world music vary across cultures and under simulated hearing loss. In this study, the term "hearing loss" is assumed to imply moderate to severe levels of hearing impairment and not a total loss of hearing ability. First, we sought to determine whether the emotions elicited by listening to particular clips of world music were correlated between Americans and Indians. Twenty emotions were selected to represent a wide spectrum of reactions that could be triggered by listening to the music clips. We hypothesized that the emotions elicited by each music clip would be positively correlated across people from these two different countries, since cross-cultural correlation of emotions in response to music has been previously demonstrated (21). Our results supported this hypothesis, and we found that of the 20 emotions studied, 8 were prominently positively correlated between Americans and Indians. We then repeated this study under simulated hearing-impaired conditions on a new set of participants. Since we conducted the surveys in a simulated hearing loss environment, we hypothesized that the emotions we found to be experienced similarly across cultures under regular hearing conditions would also be elicited under simulated hearing loss. However, results from the second phase indicated that under simulated hearing loss, different emotions were positively correlated between Americans and Indians. The emotions found to be correlated under simulated hearing-impaired conditions provide potential new insight into how hearing loss affects emotions elicited by music.

RESULTS

We conducted Internet surveys in which participants from two countries (U.S. and India) listened to brief world music clips. After listening to the clips, the participants reported the emotions elicited by the music clip from a pre-defined list of 20 emotions. The emotions used in the study were a mix of valence and arousal emotions often used to understand emotional experiences in neuroscience, as well as more nuanced categories (25, 26). For example, angry is a negative valence emotion, whereas joyful is a positive valence emotion. Exciting is an example of an arousal emotion. Emotions such as heroic, mysterious, and defiant are examples of nuanced categories of emotions that we used in this study. Each participant could choose as many emotions as they experienced from the full list of 20 for each music clip. We used 100 separate music clips for the study. Each participant listened to all 100 music clips, broken into 4 random sets of 25 clips each. We designed the experiment to mitigate potential response biases through randomization of music clips and emotion choices (**Figure 1**).

In order to precisely assess the subjective experience of emotions, we used the concept of interrater reliability to interpret the results. In this study, we defined interrater reliability as the proportion of times a particular emotion was chosen by survey participants for a particular music clip. Correlation coefficients greater than 70% can be considered to represent a strong correlation (27). For this study, we used a stricter threshold of 85% to account for potential inconsistencies in interpretation of what the emotions represented to the survey participants. We determined the range of interrater reliabilities for each emotion, with joyful having the highest interrater reliability for a single music clip of 0.91 and defiant having the lowest interrater reliability for a single music clip at 0.56 **(Figure 2**). The maximum interrater reliability value for each emotion is dependent on only one music clip, but the interrater reliabilities were distributed across the range for each emotion.

In order to determine correlations between the interrater reliabilities of the emotions elicited by each music clip for

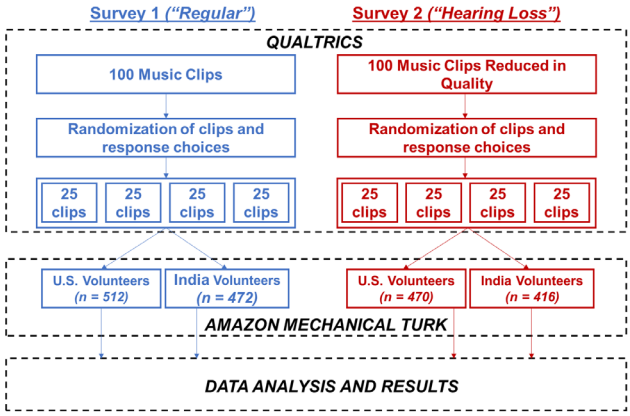

Figure 1: Experimental design. Schematic showing the experimental design for both regular hearing and simulated hearing loss scenarios. The surveys were constructed on Qualtrics, and survey participants for both surveys were recruited from the U.S. and India on Amazon Mechanical Turk. Each survey participant was presented with 100 music clips, with each survey split into four randomly chosen 25 clip units with breaks in between. The participants were allowed to choose responses from 20 pre-defined emotions, which were randomly presented. The process was repeated on a new set of participants from U.S. and India, with the music clips edited to simulate hearing loss.

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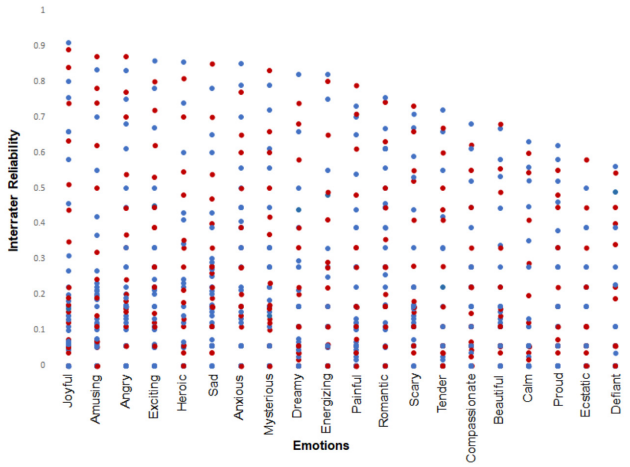

Figure 2: Interrater reliability of emotions elicited by each unedited music clip. Each dot represents one music clip. The height of the dot represents the proportion of times an emotion was chosen for that particular music clip. For example, a reliability estimate of 0.91 for joyful means that this emotion was chosen 91 times out of 100 for that particular music clip. Data from American participants is shown in blue dots, and from Indian participants is shown in red dots. Data for the regular hearing scenario is shown.

American and Indian participants, we calculated correlation coefficients. We identified the top emotions positively correlated between American and Indian participants as joyful, heroic, amusing, exciting, sad, angry, energizing, and anxious (cross-cultural interrater reliability correlation coefficient > 85%; **Figure 3**). This result provides evidence for strong positive correlation of these emotions between the two countries.

Then, we repeated the experiment on a new set of participants using the same music clips modified to simulate hearing loss. We determined the interrater reliability for all modified music clips and calculated the correlation coefficients between American and Indian participants for each emotion. For participants exposed to music clips altered to simulate hearing impairment, we identified the top emotions correlated between American and Indian participants as anxious, beautiful, scary, sad, and angry (cross-cultural interrater reliability correlation coefficient > 85%; **Figure 4**). This result suggests that while strong positive correlation of emotions continues to exist between the two countries under simulated hearing-impaired conditions, these emotions are different from the emotions identified as correlated with unaltered music clips.

Upon plotting the U.S. to India interrater reliability correlation coefficients under the simulated hearing loss scenario versus the regular hearing scenario, we found that anxious, sad, and angry emerged as the emotions that had cross-cultural interrater reliability correlation coefficients greater than 85% for both the scenarios (**Figure 5**). This result identified the three negative emotions correlated consistently between American and Indian participants, when using unaltered or altered music clips.

DISCUSSION

Our first hypothesis stated that emotions elicited by music would be similar across American and Indian participants. The results of our first experiment showed that emotions triggered by music were strongly positively correlated between participants from both countries. This result was consistent with the conclusions by Cowen, et al., who found that triumphant/heroic, compassionate/sympathetic, joyful/cheerful, amusing, exciting, sad/depressing, energizing/pump-up, and scary/fearful feelings elicited by music were correlated between American and Chinese cultures with a correlation coefficient greater than 85% (21). Several other emotions were also found to be strongly correlated, with correlation coefficients greater than 70%. Our study identified similar emotions as being correlated above 85%, except for anxious. Anxious ranked lower in the Cowen, et al. study, with a correlation coefficient of approximately 81%, but was still highly correlated across cultures. The stronger cross-cultural correlation of particular emotions in both studies might indicate that the music used in both studies were biased towards certain emotions, or that more generally, music eliciting certain emotions tends to be more commonly prevalent in societies. A broader analysis of world music would be required to determine further insights in this direction. Since we used a mix of vocal and instrumental world music in our study, this experiment further strengthened the conclusions by Cowen, et al., who used a mix of Western and Chinese instrumental music clips in their study. Our study extended the conclusions of Cowen, et al. to people from a new combination of countries – U.S., and India.

Our second hypothesis stated that emotions found positively correlated across American and Indian participants under regular hearing conditions would continue to be positively correlated under simulated hearing loss. The results from the second experiment established that emotions continued to be positively correlated across cultures under a simulated hearing loss environment. However, the emotions that were strongly positively correlated – anxious, beautiful, scary, sad, and angry – were different from the ones that predominated under regular hearing conditions. Except beautiful, all the emotions that were cross-culturally correlated above 85% in the simulated hearing loss scenario were negative in nature, when compared to the scenario where the music clips were unaltered. According to research conducted by Bigelow, et

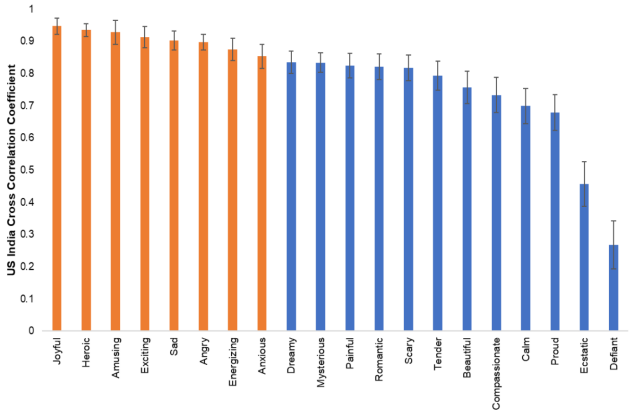

Figure 3: Cross-cultural correlation of interrater reliability for "Regular" hearing scenario. Bar chart showing the statistical correlation coefficient for different emotions elicited by unedited music clips between American and Indian participants, with standard error. The correlation coefficient was calculated using the interrater reliabilities for U.S. and India, for each emotion in the "regular" hearing scenario. The orange bars represent emotions with a cross-cultural interrater reliability correlation coefficient greater than 85%.

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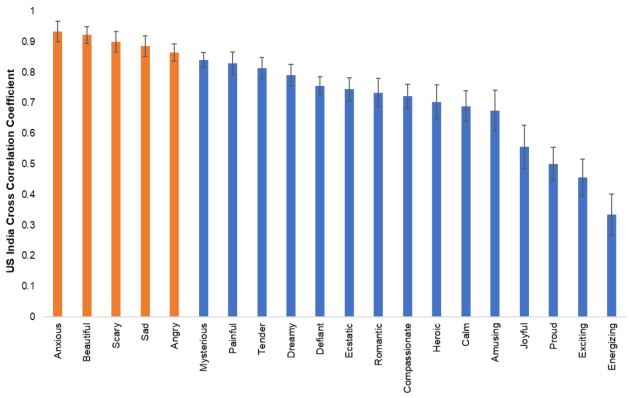

Figure 4: Cross-cultural correlation of interrater reliability for simulated "Hearing Loss" scenario. Bar chart showing the statistical correlation coefficient for different emotions elicited by music clips edited to simulate hearing loss between American and Indian participants, with standard error. The correlation coefficient was calculated using the interrater reliabilities for U.S. and India, for each emotion in the simulated hearing loss scenario. The orange bars represent emotions with a cross-cultural interrater reliability correlation coefficient greater than 85%.

al. in 2020, hearing loss was associated with both greater psychological distress and higher utilization of mental health services (28). People with hearing loss may experience music differently, and have different emotional responses compared to those without hearing loss. Further research is needed to draw more definitive conclusions in this direction.

When the cross-cultural correlations from both the experiments were viewed together, anxious, sad, and angry, which are negative emotions, had the strongest correlation coefficients. If the threshold for the cross-cultural interrater reliability correlation coefficients for both scenarios was dropped from 85% to a still very strong 80%, anxious, scary, sad, angry, mysterious, and painful emerged as the most correlated emotions under both experiments. The fact that none of the positive emotions considered rose to the top in terms of being strongly correlated under both scenarios is notable and requires further in-depth research.

Our study did not provide a comparative analysis of the strength of the emotions triggered. We did not track the order or primacy of emotions relative to each other for individual music clips. Additional surveys using, for example, a 9-point Likert scale are needed to fully understand the strength of these emotions relative to each other. Such experiments could be used to test the relative strength of negative emotions compared to positive emotions for people with normal hearing versus people with hearing loss.

Along with demonstrating the correlation of emotions on a cross-cultural basis, the data collected from this project will be useful in the field of audiology, particularly to those who design background music for various settings. Technical features of the music clips that generated high correlations in this study can be analyzed to inform the creation of background music that is more likely to trigger desirable emotions. Psychology-based and neuroscience-based research on affective disorders and hearing loss will also benefit from the data and insights of this study.

Hearing loss occurs on a wide spectrum, making it challenging to obtain a sufficiently large and verifiable sample size to conduct a controlled experiment. Therefore, our second experiment was conducted by distorting the music clips to simulate a hearing loss scenario. By uniformly modifying the music clips to simulate specific levels of hearing loss, we eliminated the variance that would have otherwise existed between hearing-impaired participants due to the unique circumstances of their hearing loss. The simulated hearing loss scenario was limited by the fact that the experiment was not conducted on individuals with impaired hearing. The distortion introduced into the music clips to simulate hearing loss could be a potential factor which influenced a shift towards the negative emotions observed under this scenario. Since the study did not verify if any of the participants in either survey had true hearing loss, it was also possible that responses from some hearing-impaired participants may have influenced the results. Therefore, future surveys should be tested in populations that are truly hearing-impaired in order to verify the results from our study.

Additional confounding factors such as the age, sex, and familiarity with music of the survey participants might have affected the results. We collected age data for the survey participants. About 55% of the respondents to the surveys for experiment 1 were of ages 18-40, versus 49% for experiment 2. Potential differences in interpretation of the emotion words could be another factor which influenced results. The emotion words were not translated into native Indian languages for the Indian participants in the surveys.

Further insights can be obtained from the data set we generated. By using Monte Carlo simulations, a customized predictive data model can be developed. The objective of such a model could be to predict the emotions triggered based on objective technical attributes of the music clips. Being able to predict cross-cultural experiences of a particular music clip could help curate music with desired attributes and can make the targeting of music to specific situations – for example, waiting music on the phone or therapeutic music during clinical treatments – more effective cross-culturally. As a next stage of the project, a preliminary version of this model is

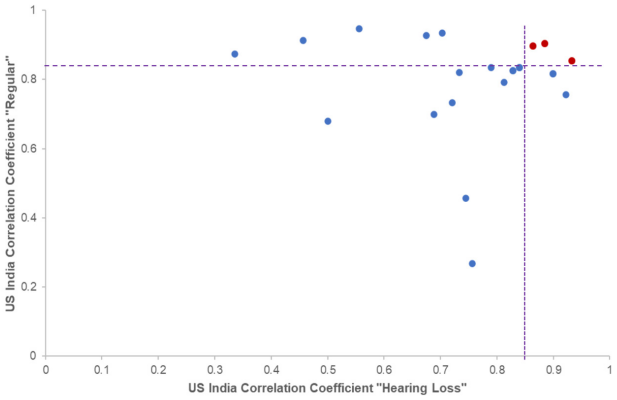

Figure 5. Strongest cross-cultural interrater reliability correlations between regular hearing and simulated hearing loss scenarios. Scatter plot showing the statistical correlation coefficients for each emotion elicited by music clips between American and Indian participants with the simulated hearing loss scenario on x-axis and the "regular" scenario on y-axis. The red dots represent the emotions that had cross-cultural interrater reliability correlation coefficients greater than 85% for both experiments: anxious, sad, and angry. The purple dotted lines represent 85% thresholds for the correlation coefficients under both scenarios.

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being developed.

The results of the experiments supported the hypothesis that emotions elicited by music would be similar across people from U.S. and India and provided additional color in support of the universality of music across cultures. The results of the second experiment did not support our hypothesis that emotions found to be elicited similarly across cultures would continue to be positively correlated when the music clips were altered to simulate hearing loss. We showed that while emotions continued to be positively correlated cross-culturally, the correlated emotions were different from the ones identified when the music clips were unaltered. This insight provides new direction for continued research on the strength of these emotions and has potential clinical, theoretical, and practical applications for entities that serve and study communities with hearing loss.

MATERIALS AND METHODS

Our first hypothesis was tested with an experiment conducted using surveys, where participants from two countries (U.S. and India) listened to music clips. The Amazon Mechanical Turk platform was used to screen all survey participants for their respective geographies of residence while taking the surveys. After listening to the clips, participants were asked to select the emotions the music clip elicited from a pre-determined list of 20 emotions. Participants were allowed to choose as many emotions as needed after listening to each music clip. All emotion words were given in English. 100 separate music clips were used for the study. These clips were a combination of world music taken from the National History of Song project, with the permission of Dr. Samuel Mehr at the Yale University's School of Medicine, and instrumental clips used by Cowen, et al., with approval from that group (20, 21). World music in the context of this study implied culturally diverse music sourced from indigenous cultures around the world (20). Of the music clips, 32% were comprised purely of vocals, 27% consisted of pure instrumental music, and 41% contained both vocals and music instruments. The music clips with vocals consisted of solo male and female voices, as well as ethnic groups and chants. The instrumental clips consisted of a mix of ethnic instruments of unknown origin, as well as readily recognizable and classically Western instruments such as the piano, percussion, and strings. The average music clip was 12 seconds in length, with the shortest being 5 seconds long and the longest being 35 seconds long. The survey did not query if any of the participants had real hearing loss.

To assess cross-cultural similarities and dissimilarities in emotions, data on the emotions elicited by the music as reported by the participants across 20 separate emotions was collected. The emotions in the surveys were: amusing, angry, anxious, beautiful, calm, compassionate, defiant, dreamy, ecstatic, energizing, exciting, heroic, joyful, mysterious, painful, proud, romantic, sad, scary, and tender. These emotions were chosen from the Cowen, et al. study with the objective of keeping the emotion categories sufficiently broad but not significantly overlapping (21). The data was then analyzed to understand what proportion of respondents across the two cultures displayed the same emotions after listening to the same music clip, and how correlated these emotions were.

The surveys were constructed using the Qualtrics platform. The sequence of music exposure in the surveys was randomized to ensure no sequencing bias. The response choices within the surveys were also randomized to eliminate any bias towards a particular choice. Each survey participant listened to all 100 music clips, broken into four 25 clip units. Each participant was provided the full list of 20 emotions for each song, and they could select multiple emotion choices as responses. Prior to conducting the experiment and launching the surveys, the project proposal, experiment design, and survey methodology were examined and formally approved by the Institutional Review Board of the High Tech High School in Secaucus, NJ. Informed consent was sought on the surveys as required by the Board. To test our first hypothesis, a total of 984 distinct participants were recruited for the study using the Amazon Mechanical Turk platform, with roughly 52% of the participants being from the U.S. and the remaining from India (48%). Participation was voluntary, and the participants were informed of their ability to leave the survey at any time. Each participant was compensated $0.50 upon completing the survey.

To test our second hypothesis, the experiment was repeated, but the music clips were modified to simulate hearing loss, thereby lowering the richness of the listening experience. The music clips were reduced in quality by lowering the amplitude sensitivity by 50 dB at frequencies of 2,000 Hz and above and by limiting the frequency range to 5,000 Hz. These levels correspond to moderate to severe hearing loss and are consistent with how hearing loss is typically evaluated (29). The music distortion was accomplished using software from Audacity, the University College London's Hearing Loss Demonstrator software, as well as the NIOSH Hearing Loss Simulator made available by the Centers for Disease Control and Prevention. Surveys for the second phase were then conducted on a new group of 886 participants in the same manner as the first phase. This group consisted of approximately 53% participants from the U.S. and the remaining from India (47%).

Survey data was obtained from the Qualtrics platform at the level of one row per music clip and was aggregated into 4 data sets – one per country, per experiment. Interrater reliability was calculated for every music clip per emotion in each data set, as the proportion of times that a specific emotion was chosen for that particular music clip. The Pearson correlation coefficient was then calculated between the interrater reliabilities for American and Indian cultures, for each emotion, in both the experiments, using the formula:

where x_i and y_i represent the interrater reliability data points for

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}},$$

American and Indian participants respectively for each of the music clips, and $\bar{x}$ and $\bar{y}$ represent the mean of the interrater reliabilities for American and Indian participants, respectively, for a specific emotion.

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