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Consumer Headphones Improve Music Appreciation in Patients with Hearing Loss

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Introduction

It is well known that patients with varying degrees and configurations of hearing loss often find it difficult to enjoy music given current technology limitations.[1,2] Approximately one third of the population with hearing loss have reported reduced enjoyment of music.[3] Furthermore, hearing aids have been insufficient in restoring music enjoyment to the majority of the population with only 41% of hearing aid users reporting that hearing aids make music more enjoyable.[3,4] Hearing aids are intended to improve audibility of speech, which is very different than music acoustically. As a result, people with hearing loss complain that listening to music with their hearing aids causes feedback, distortion, excessive loudness, inadequate audibility of soft sounds, reduced tone quality, and unbalanced frequency response.[5,6]

To overcome these constraints, there have been developments in advanced consumer electronics that allow manufacturers to design and develop audio devices that are geared toward individual listening needs. The Even headphones use a technology called the EarPrint to customize the headphones to each listener's hearing levels. During the EarPrint measurement, a voice assistant instructs the user to press a button when a short piece of music becomes audible. These music pieces are constructed with a narrow-band spectrum of varies frequencies.[7] The Even headphones then produces a specific profile of the individual's hearing and applies gains to the output music accordingly to compensate for the hearing loss.[7] Research has compared Even headphone thresholds to audiometric thresholds and found that Even headphones can provide relatively accurate information on the listener's hearing sensitivity.[7,8] The purpose of this study is to measure the general subjective improvement of music appreciation and various music qualities with the use of the Even headphones.

Method

This study was approved by the Institutional Review Board at the University of the Pacific. A total of 25 subjects were recruited from the University of the Pacific Hearing and Balance Center in San Francisco, CA. Subjects were included in the study if they had a hearing loss of mild severity or worse. The subjects varied in age, gender, degree of hearing loss, type of hearing loss, duration of hearing loss, and amplification usage.

All subjects were asked to pick a piece of music of their choice from Spotify and listen to it from the Even Headphones (MeQ Inc dba Even, El Cerrito, CA) through a tablet (Lenovo Tab M7. Lenovo, Morrisville, NC). They set the volume of the tablet to their most comfortable level (MCL). This volume level was recorded by the researcher and the level was not changed throughout the rest of the process. After listening to the piece of music for approximately 30 seconds without the EarPrint adjustment, the subjects completed the questionnaire survey (Table 1). Subjects could ask for clarification about any of the questions in the survey.

Table 1. Questions Presented to the Participants Pre- and Post- "EarPrint"

Question 1	In general, how did the music sound to you?
Question 2	How did the bass (low pitches) sound to you?
Question 3	How did the treble (high pitches) sound to you?
Question 4	How was the loudness of the music?
Question 5	How was the timbre of the music?
Question 6	How was the melody of the music?
Question 7	Do you think the change in the headphone improved your appreciation of music?

Responses were recorded using a Likert scale from 1 to 10, with 1 being "not good whatsoever", 5 being "somewhat good", and 10 being "extremely good". Question 7 was only included in the post- condition.

The subject then completed the Even EarPrint measurements. The subject listened to the same piece of music, now with their individualized EarPrint turned on. After approximately 30 seconds of listening, the subjects completed the same questionnaire (Table 1). Questions 1 through 6 were the same questions from the pre- questionnaire. Question 7 was only asked in the post- condition.

Participants' responses from the pre- and post- questionnaire were coded and analyzed to determine the statistical significance of changes regarding these aspects of music and the participants' perceptions. A within subject non-parametric Wilcoxon signed-rank test was utilized in this evaluation (? = 0.05).

Results

The results from the pre- and post- surveys were evaluated using the Wilcoxon signed-rank test and found significant shifts in perceived quality for all survey questions. The following figures are histograms that represent the participant responses on the pre-survey (blue bars) and the post-survey (green bars).

Overall Music Quality

Participants' perceptions of the overall music quality before and after the EarPrint adjustment was evaluated (Figure 1). Results revealed a significant increase ($p < 0.01$) in the Likert scale scores obtained for Question 1 "In general, how did the music sound to you?", before and after the EarPrint adjustment made by the headphones. Such a result suggests a much-improved perceived overall quality in music for the participants.

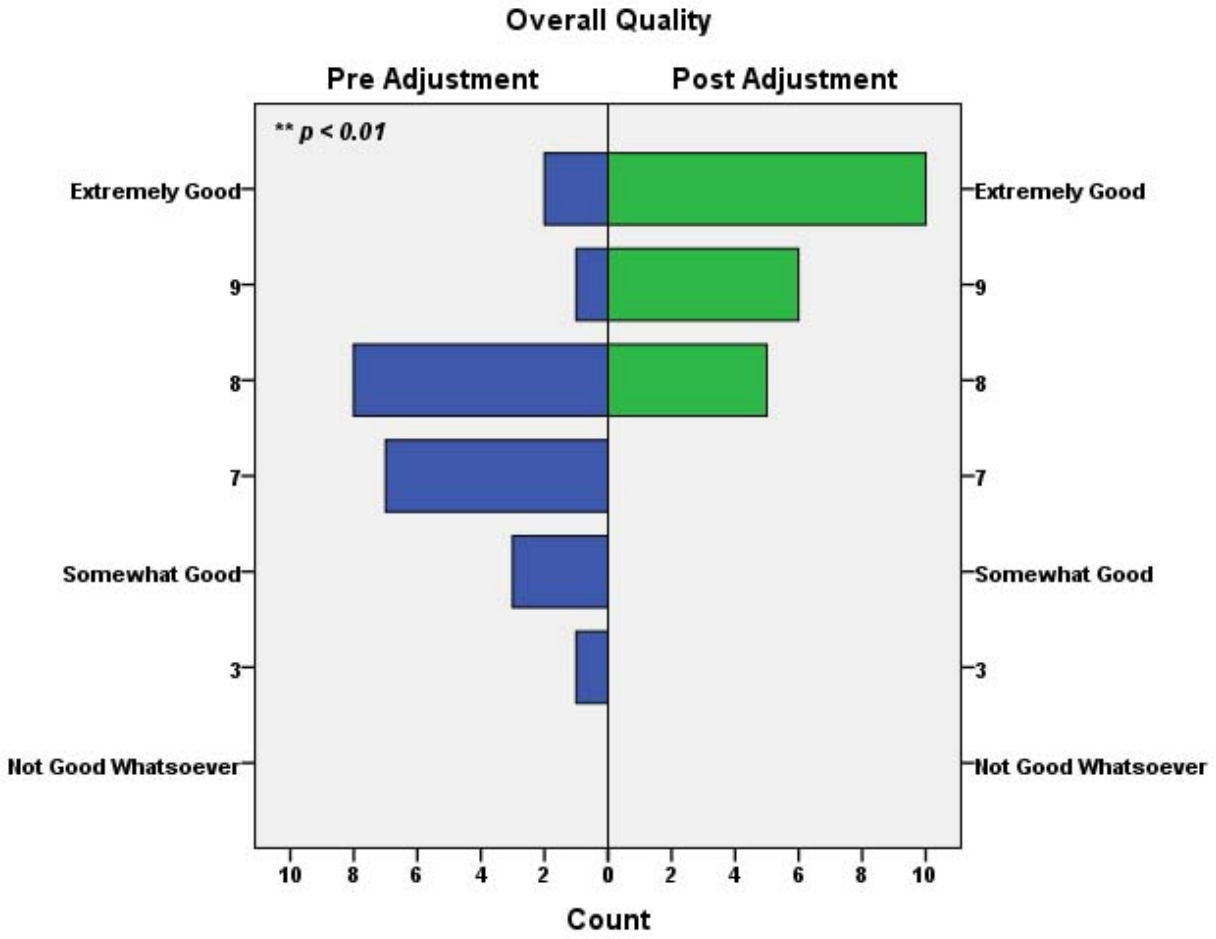

Figure 1. Responses to Question 1 "In general, how did the music sound to you?" Left and right panels with blue and green bars represent histograms of participants' responses to the question before and after the EarPrint adjustment, respectively.

Specific Music Characteristics

Participants' perceptions of the specific music characteristics before and after the EarPrint adjustment were also evaluated (Figures 2–6). Result revealed a significant increase in the Likert scale scores obtained for questions regarding the bass ($p < 0.01$), treble ($p < 0.01$), loudness ($p < 0.01$), timbre ($p < 0.01$), and melody ($p < 0.05$) before and after the EarPrint adjustment made by the headphones. These results suggest much-improved perceived quality in almost all aspects of the music for the participants.

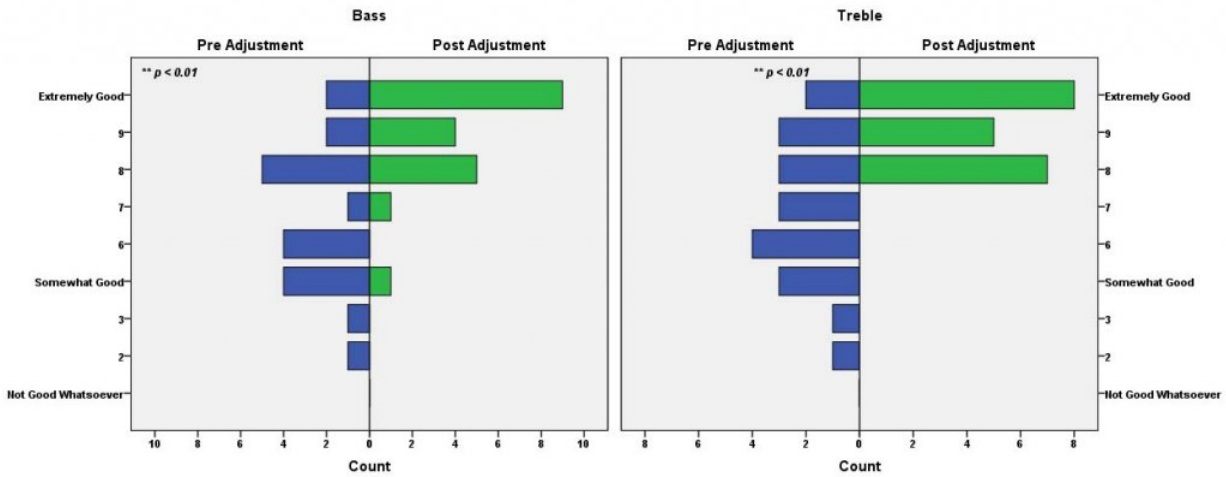

Figure 2. Responses to Question 2 “How did the bass (low pitches) sound to you?” and Question 3 “How did the treble (high pitches) sound to you?” Left and right panels with blue and green bars represent histograms of participants’ responses to questions before and after the EarPrint adjustment, respectively.

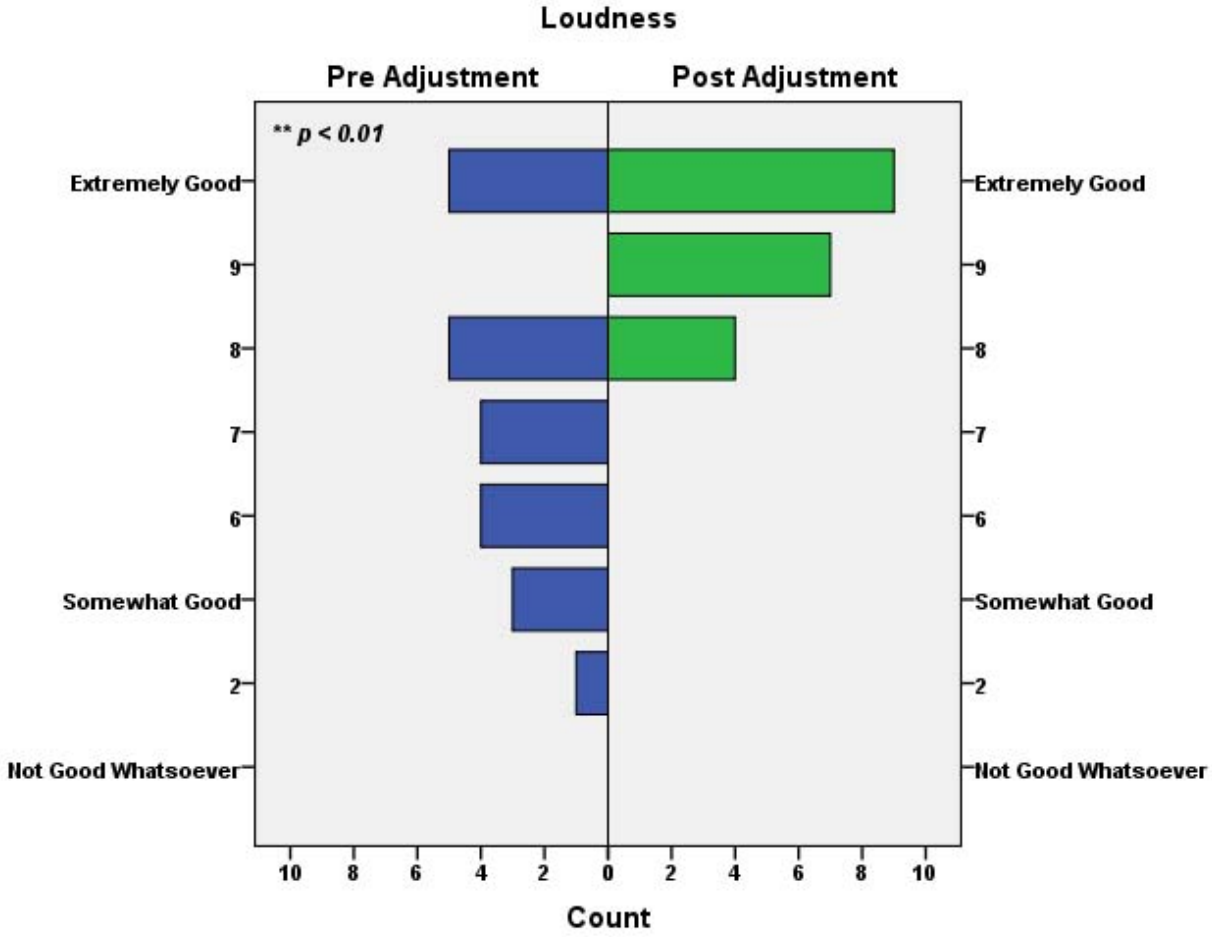

Figure 3. Responses to Question 4 “How was the loudness of the music?” Left and right panels with blue and green bars represent histograms of participants’ responses to questions before and after the EarPrint adjustment, respectively.

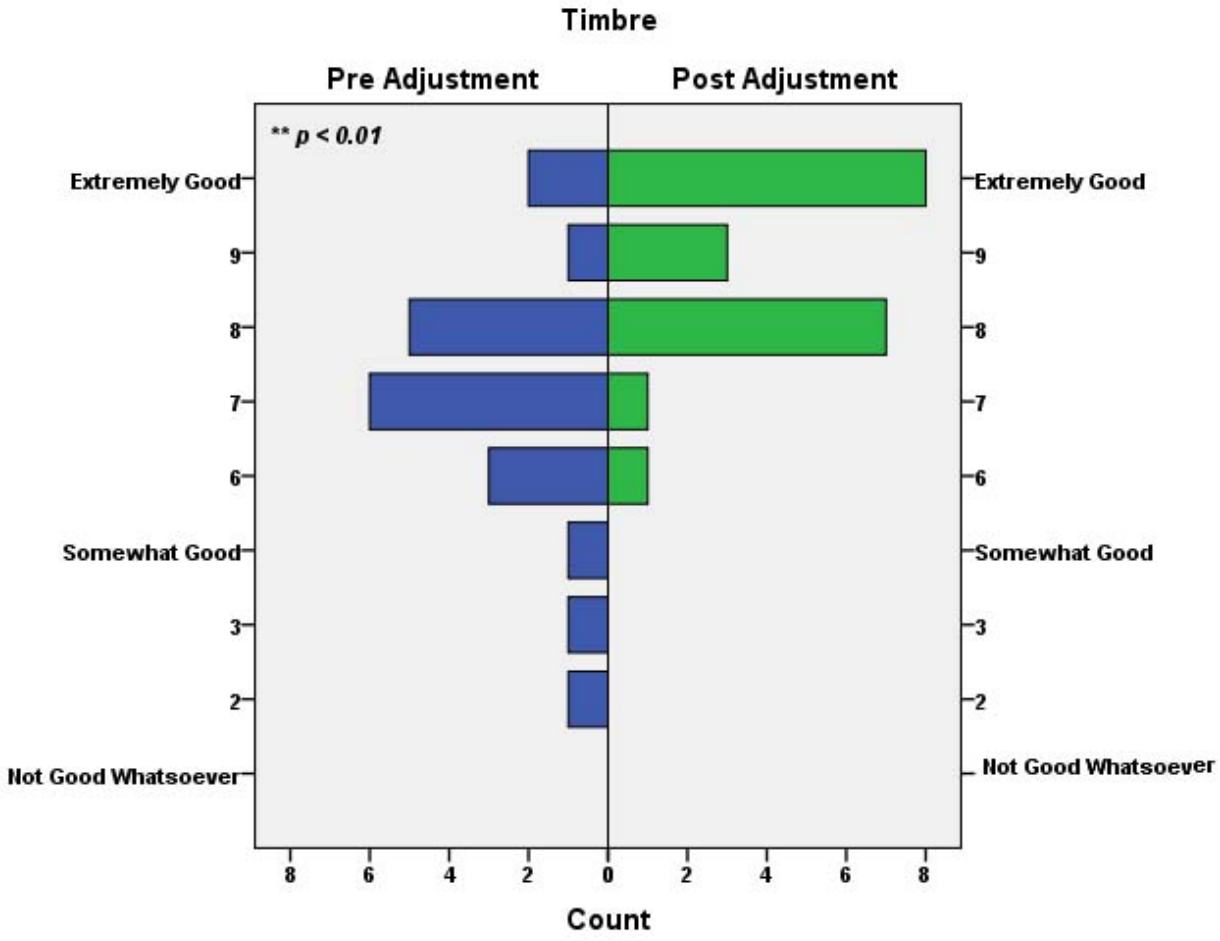

Figure 4. Responses to Question 5 "How was the timbre of the music?". Left and right panels with blue and green bars represent histograms of participants' responses to questions before and after the EarPrint adjustment, respectively.

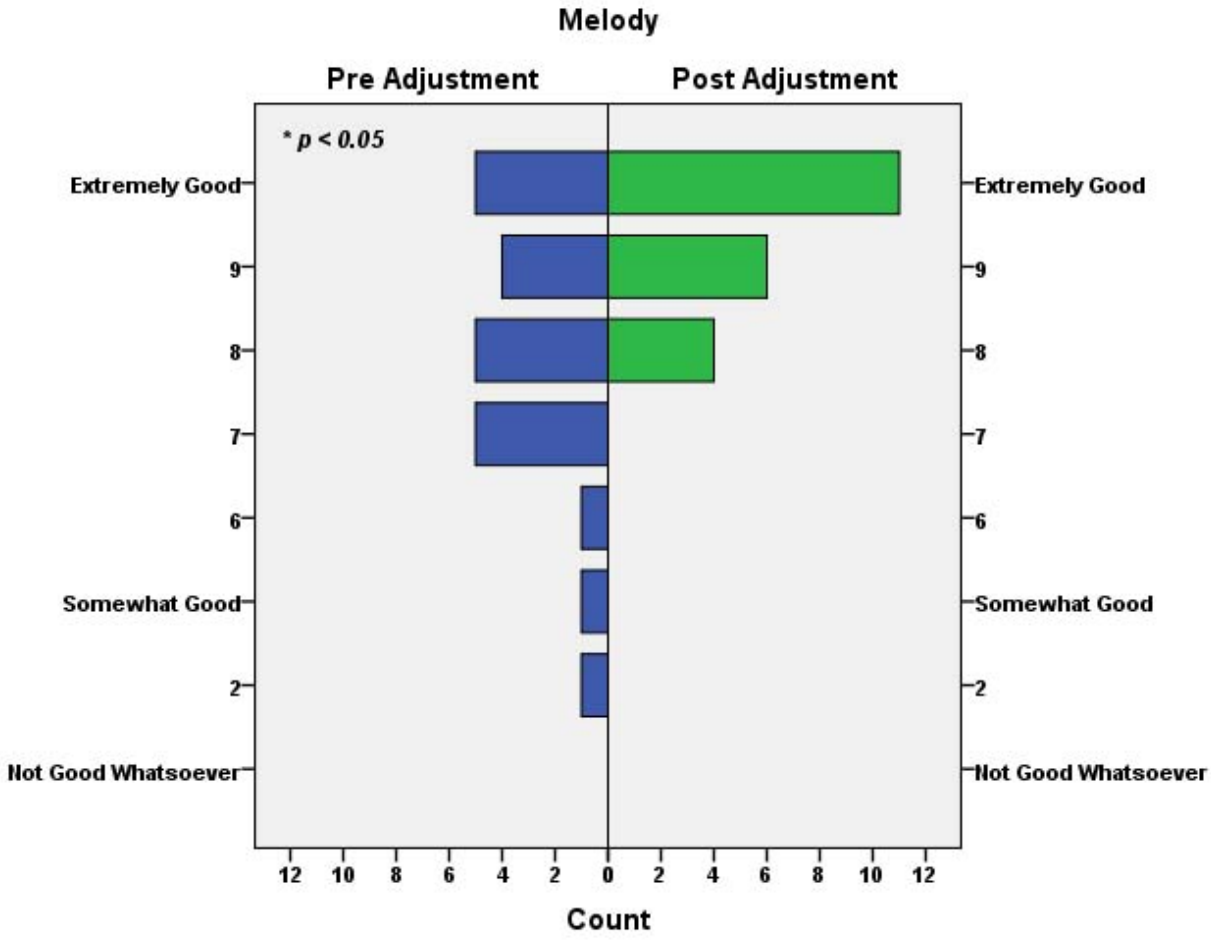

Figure 5. Responses to Question 6 "How was the melody of the music?". Left and right panels with blue and green bars represent histograms of participants' responses to questions before and after the EarPrint adjustment, respectively.

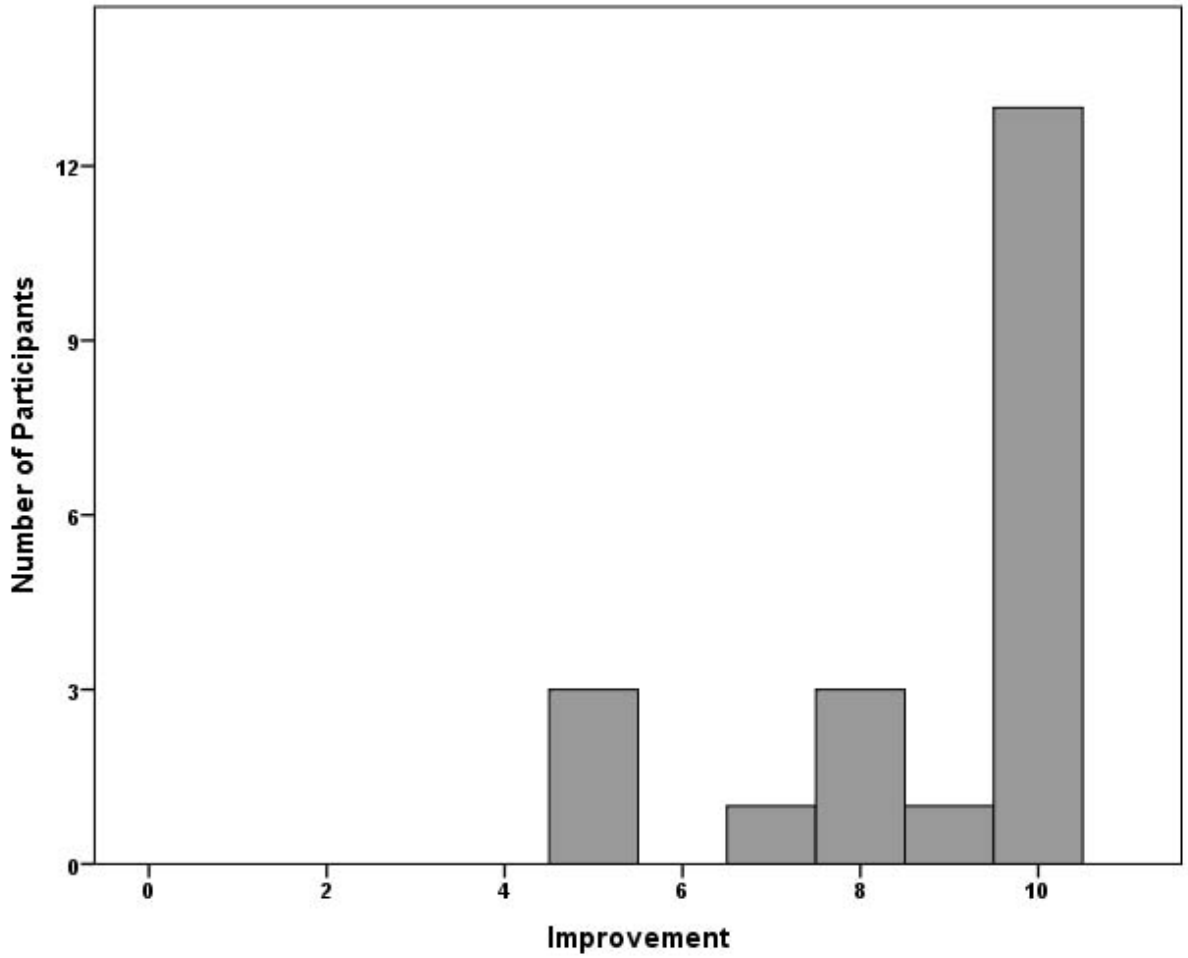

Figure 6. Histogram of the responses to Question 7 “Do you think the change in the headphone improved your appreciation of music?” Likert scale of improvement ranges from 1 to 10, with 1 being “Not improved whatsoever,” 5 being “Somewhat improved,” to 10 being “Extremely improved.”

Overall Improvement

Question 7 of the Post-EarPrint questionnaire asked the participants “Do you think the changes in the headphones improved your appreciation of music?”. Responses were also recorded using a Likert scale from 1 to 10, with 1 being “Not improved whatsoever,” 5 being “Somewhat improved,” and 10 being “Extremely improved.”

Results obtained from this question revealed that all subjects reported that their appreciation of music was at least “Somewhat improved” after the EarPrint adjustment, with the majority of subjects reporting an extreme improvement (see Figure 6).

Conclusion

Results from this study provide evidence that consumer grade headphones could help improve the appreciation of music in patients with hearing impairment. There was a clear and significant improvement in perceived quality of music (including bass, tremble, timbre, loudness, melody, and overall quality) with the EarPrint adjustment. Furthermore, all subjects reported an improvement in music appreciation with the EarPrint adjustment, with most of the subjects reporting an extreme improvement. This demonstrates that in addition to traditional treatment for hearing loss (such as amplification), well designed consumer electronic devices may provide a cost-effective way to

help hearing loss patients regain enjoyment of music.

The future direction of this study includes determining if different degrees, severity, and types of hearing impairment would equally benefit from these headphones. The researchers are also interested in investigating if a placebo trial (i.e., not actually enabling the EarPrint and instead just turning up the volume slightly) would be yield similar results. Furthermore, there could also be a comparison between the performance of Even headphones with other consumer headphones with similar functionalities.

Disclaimer

Jiong Hu, PhD, AuD is a member of the advisory board of MeQ Inc dba Even, El Cerrito, CA

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