Hearing Technologies

Blind Study: Mimi Personalized Sound is Highly Preferred by Listeners

Mimi Hearing Technologies

Abstract

The goal of Mimi's biologically inspired algorithm is to personalize sound by adapting audio to the listener's unique hearing ability and restore missing details.
The present online study was conducted to blindly assess listeners' subjective preferences comparing Mimi processing and the unprocessed original. Participants performed two listening tasks: First, their favorite processing strength was determined. Secondly, the participants blindly selected their preferred version between Mimi processing and the original sound.
The vast majority preferred Mimi processing over the unprocessed original. The subjective benefit was independent of a user's level of hearing loss as well as the tested musical content.

Introduction

Mimi Sound Personalization is currently available on more than 20 headphones, enabling users to consume audio tailored to their hearing. Based on a user's audiogram, Mimi adjusts more than 100 parameters that control its sound engine. Mimi's algorithm is a real-time simulation of the sound processing that occurs within the human ear. Its goal is to compensate for loudness loss. The present study aims at evaluating the subjective benefit of Mimi processing for a variety of hearing profiles: Do participants prefer personalized audio with Mimi processing? We want to blindly assess the current status quo of Mimi's listening experience without the influence of the whole user experience, like visual interfaces, labels, or branding.

Methods

Setup: The study was conducted remotely, using a software for listening experiments that was built by Mimi.

Prerequisites: All potential participants were asked to do a pure-tone threshold hearing test on their iOS device with the Mimi Hearing Test app, a certified medical product, and their own Apple headphones. If they completed the hearing test in a quiet environment, presented complete audiograms for each ear and had symmetric hearing[1], they were invited to participate in the study.

Participants: We recruited participants via the online research platform Prolific who were fluent English speakers, iPhone users, and 20 years or older. To ensure data quality, we assessed participants' ability to meaningfully complete the listening tasks[2]. Subsequently, data of 78 participants could be analyzed.

The participants comprised 32 females (41%) and 46 males. Ages ranged from 21 to 72 years,with a median age of 35 years. The distribution of their hearing loss (based on the audiogram averaged across both ears) is shown in Figure 1.

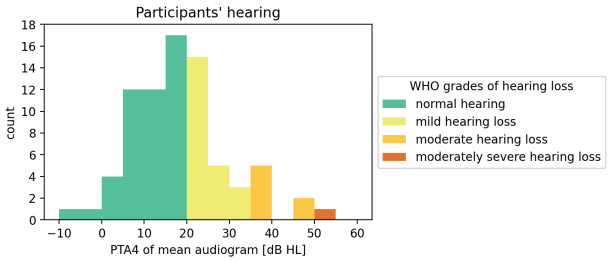

Figure 1: Hearing of participants
Distribution of the pure-tone average of thresholds at 500, 1k, 2k, and 4k Hz (PTA4)

[1] Hearing was defined to be symmetrical if the absolute difference between the thresholds of both ears was equal or below 20 dB HL for at least five out of six frequencies.
[2] Inclusion criteria were based on ratings of the hidden reference (MUSHRA) and limiting the number of contradicting ratings.

Following the definition of hearing loss grades by the WHO, the study included participants with normal hearing, as well as with mild, moderate, and moderately severe hearing loss.

Music stimuli: We used 7 to 10 second-long looped snippets of the following 5 songs covering various genres[3]:

- *Trip* by Siine ft. Le June (Pop),
- *Ev'rybody wants to be a cat* by Roy Hargrove (Jazz),
- *So hot you're hurting my feelings* by Caroline Polachek (Indie Pop),
- *Money* by Pink Floyd (Rock),
- *Arlandria* by Foo Fighters (Alternative).

Step 1: Determining the Best Individual Processing Strength

Users of headphones with Mimi Sound Personalization have the option to fine-tune their first fit based on their hearing according to their subjective taste. In the headphone companion apps, users can choose between "recommended", "softer", and "richer" processings, which audibly differ in strength of loudness loss compensation. In the first part of the study, a MUSHRA[4]-like listening task was used to determine each participant's favorite fine-tuning option.

For each of the five sound snippets, participants blindly compared their respective fine-tuning options against one another and the unprocessed original. The latter was also included within the test conditions as a hidden reference to determine participants' response reliability. Each condition was rated by moving a slider on a rating scale. The scale allowed negative as well as positive ratings and was divided into five equal intervals with descriptions ranging from "clearly worse" to "clearly better", see Figure 2 below.

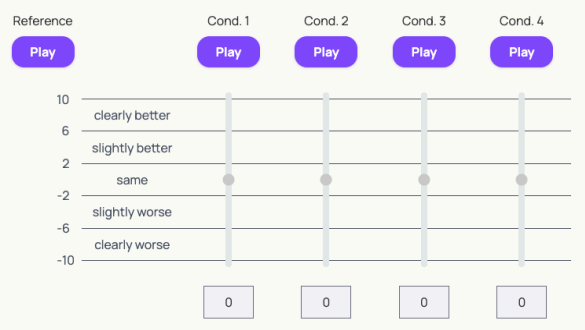

Figure 2: Interface of the first task

Based on the results, the highest rated fine-tuning condition was determined for each trial (song). These conditions were assumed to be the best individual fine-tuning choices.

Step 2: Evaluation of Sound Preference

To confirm whether participants reliably prefer Mimi processing[5], the main part of the study was a blind A/B comparison. For all five music snippets, participants were asked to indicate their preference between the unprocessed original and their favorite fine-tuning condition (it was also possible to indicate that one could not hear a difference between the 2 presented versions).

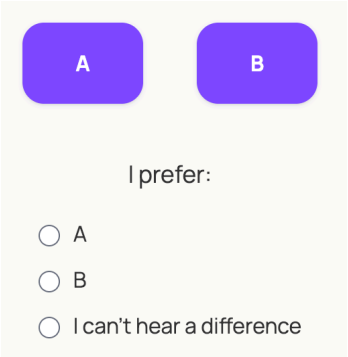

Figure 3: Interface of the second task
Participants were asked to listen to both samples and decide which one they prefer.

[3] Genres according to Shazam
[4] Recommendation ITU-R BS.1534-3

[5] In former studies, naive listeners reported that MUSHRA-like tasks were quite challenging to them. Hence, its use in this study was primarily to blindly determine the best fine-tuning condition. The subsequent A/B test enabled participants to choose their preferred processing version (original or Mimi processing) more confidently.

Results and Discussion

Summarizing the blind A/B choices on an individual level, we determined whether the original sound or Mimi processing was preferred in the majority of trials (songs) for each participant. The results can be seen in Figure 4:

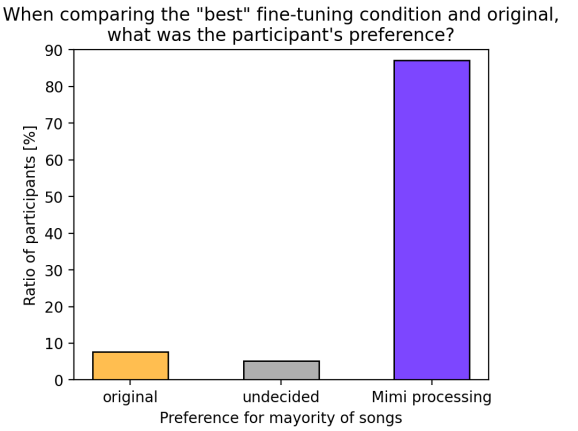

Figure 4: Preference for Mimi processing compared to original
What percentage of participants chose either condition for the majority of songs?

Notably, the vast majority of participants (87.2%) preferred the sound with Mimi processing for the majority of songs. 5.1% of participants were split in their processing choices, meaning that they chose both processing versions for the same number of songs and "I can't hear a difference" for the remaining ones. Additional 7.7% chose the original more often than the option with Mimi processing.

In the MUSHRA-like listening task, participants rated each fine-tuning option in comparison with the original and one another. This provided insights into the participants' preference as well as the strength of it. In about 60% of trials, the "recommended" fine-tuning option was rated higher than the original. Furthermore, at least one of the three fine-tuning options was preferred over the original in 87.2% of trials. The best fine-tuning choice was rated considerably and significantly higher than the original (mean of 4.1 on a scale ranging from -10 to 10)[6]. These results made the advantages of offering different processing intensities apparent: The fine-tuning options took individual preferences into account which increased the likelihood that participants were offered at least one strongly preferred processing version.

It is difficult to say why there was a small group of participants who did not benefit from Mimi processing. It is possible that people with hearing loss need to accustom themselves to the change[7] or that the limited fine-tuning options cannot account for all individual subjective preference.

One could assume that people without hearing loss do not benefit from Mimi processing as there is no hearing loss to compensate for. However, the presented findings didn't vary significantly between participants with and without hearing loss. Both groups showed a clear preference for Mimi processing. This can be explained by a closer look at the definition of normal hearing.

According to WHO, people with normal hearing experience no to minimal problems hearing everyday sounds, nevertheless, they might already have raised thresholds at some frequencies. Hence, we believe that the "clinical" criteria for hearing loss is not appropriate to determine the likelihood of a benefit from music processing (e.g. PTA4 is covering only a narrow range of frequencies in respect to what is relevant for music).

Finally, we want to highlight that Mimi processing was used with the same parameters across all content. Even though we tested a wide variety of music material in this study, Mimi provided a comparable benefit for all of them. Music with a low dynamic range like *Arlandria* could similarly benefit from Mimi processing as

[6] This mean was significantly higher than the mean of a Monte Carlo experiment where the best rating out of 3 randomly distributed variables was chosen. The variables were drawn from a normal distribution with zero mean and the same standard deviation as the hidden reference ratings.
[7] In the hearing aid industry, it is known that people need time to accommodate / adapt before they benefit from stronger compensation.

content with a wider dynamic range, such as *Ev'rybody wants to be a cat*. This highlights the unique flexibility and adaptability due to Mimi's biologically inspired and patented processing.

Summary

The overall goal of this study was to assess the subjective benefit provided by Mimi processing. We observed the following:

- Mimi processing provided a clear audible benefit to most users. On an individual level, about 9 out of 10 participants preferred Mimi over the unprocessed original.
- The strong preference for Mimi processing was demonstrated in both the blind MUSHRA listen task, as well as the blind A/B comparisons.
- The clear benefit was reported by participants independent of their level of hearing loss.
- Mimi processing is remarkably flexible, as the preference for it was robust across a variety of music genres.
- Fine-tuning options increased the likelihood that participants were offered at least one strongly preferred processing version, as these options account for subjective preferences.

We can conclude that Mimi processing is a major sound quality improvement for the vast majority of participants.

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2024

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