Listening Level Study

Mimi Hearing Technologies

Abstract

Mimi's solution to offer Sound Personalization for people with various hearing abilities serves the purpose of providing a benefit to users and making details of sound that would otherwise be lost audible again. Mimi's hearing loss restoration paradigm leads to more detail for individual users and in theory should therefore also allow them to listen to music at a lower volume. WHO and ITU defined a global standard that defines sound dose as a metric to quantify the load for the auditory system that is produced by media. An online study was conducted in which participants listened to personalized sound while adjusting their preferred listening volume. Volume and sound dose were calculated and compared to the cases in which unprocessed sound was presented. Results show that, on average, listeners of various hearing abilities lower the playback volume and receive a significantly lower sound dose when listening to media with Mimi.

Introduction

Mimi's sound personalization helps people with various levels of hearing ability to have a better listening experience by compensating for hearing loss during media consumption. This means that relevant details and information that would otherwise be lost are being restored. Mimi's processing is tuned in such a way that this increase in detail comes without an increase in physical volume, which helps to address the hearing wellbeing of listeners in a more holistic way rather than simply adding volume. However, in this context it might be helpful to define what volume increase actually means. A more accurate measure is achieved by assessing the sound energy that a user receives. WHO and ITU have established a global standard[1] that defines so-called sound dose as "the total quantity of sound received by the human ear during a specified period." To calculate this sound dose, a whole variety of things has to be considered: knowledge of the device's output volume as well as statistics of the media or music content itself. In addition, the headphone sensitivity curve and any digital signal processing effects (DSP) also have to be included into the equation. In practice, it is often very difficult to obtain the exact sound pressure level on an arbitrary playback device for a given headphone, song snippet and DSP combination. This is when relative comparisons become helpful. To compare the effect of our processing against an unprocessed scenario we don't need to know the absolute sound pressure level a listener receives, but are simply drawing conclusions about relative sound dose changes between these two different cases.
This requires a simple, but strong assumption: The device volume level for processed sound is equal to unprocessed sound.
Based on this assumption, our calculations with a large headphone data set and various types of audio media content show that the processing our listeners receive on average does not only provide more detail but also a decrease in sound dose. Besides meaningful hearing loss compensation, this represents an additional benefit. But the sound dose decrease also exists for listeners with normal hearing, a user group that does not require any compensation but still receives a slight sound enhancement leading to more clarity and detail.

While the above stated assumption about the volume level seems logical when people receive processed sound which provides more detail, we still wanted to validate this in a study and answer the following questions:

- What are people doing with the volume control of the device when listening to sound that was processed with Mimi?
- Are people really receiving a lower sound dose with Mimi?

[1] https://apps.who.int/iris/bitstream/ handle/10665/280085/9789241515276-eng.pdf

How we did it

Participants and headphones

To test the hypothesis that Mimi users receive a lower sound dose, knowledge about the particular headphone a participant is using during the study is required. We therefore asked the participants to select their headphone model in an online questionnaire's drop-down menu which contained over 400 different models. The questionnaire was also used to ask for the participants' self-assessed hearing ability. Only participants without hearing aids or cochlear implants were allowed to participate in the online study.

We conducted the online study with ~ 100 participants. Participants' ages ranged from 19 to 68 years with a median age of 27 years. Hearing ability, as tested using our online Masked Threshold (MT) test, ranged from normal hearing over slight to mild hearing impairment, while the majority of participants had a slight form of hearing impairment. We ensured an equal distribution between male and female participants. 58 different headphones were used among participants. Headphone brands Apple, Sony and JBL dominated the headphone distribution among participants, as seen in the plots below. JBL sticks out among top brands with ten different headphone

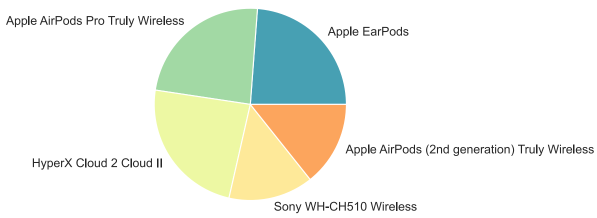


Fig: Top 5 headphone models in the study

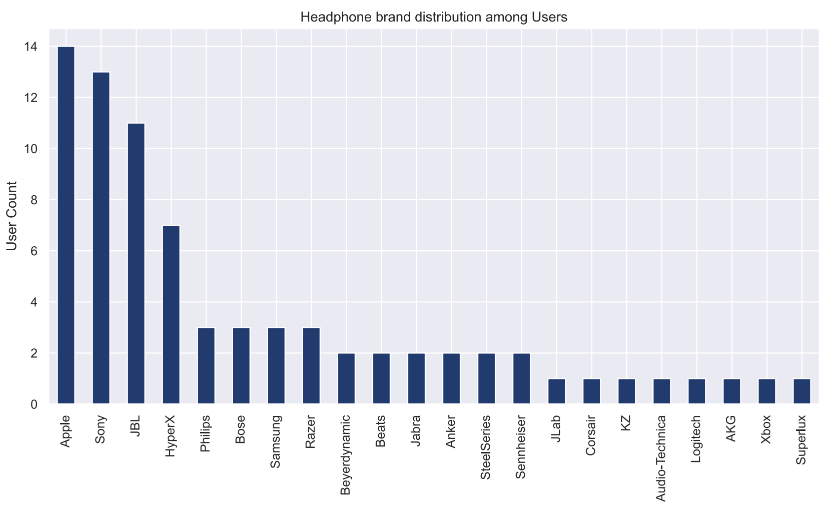


Fig: Headphone brand distribution among users

General Setup

The general challenge of this study was to simulate a real-life situation as closely as possible. We first asked participants to conduct a hearing test (MT test) and the test result was used to lead them on further to a custom listening test page suiting their hearing ability. Because the study involves individual volume adjustment for different tracks, the first task that participants were asked to do was adjust their system volume to a preferred volume while a short classical music snippet was playing. Participants were then instructed not to touch the system level again during the whole test. Participants were then presented with different stimuli (musical pieces from genres Pop, Jazz and Electro, and one movie trailer piece) in a randomized order. Each audio file was presented in an unprocessed version and several processed versions to include a variety of fitting strengths per listener. All audio files were presented at a much lower volume (-20dB) than the first setup track. This meant that the following stimuli playing back in the study were much quieter than the first sound snippet at the self-adjusted initial playback volume. Participants were instructed to use + and - buttons on each page to adjust the volume to their preferred listening level by clicking or holding the buttons.

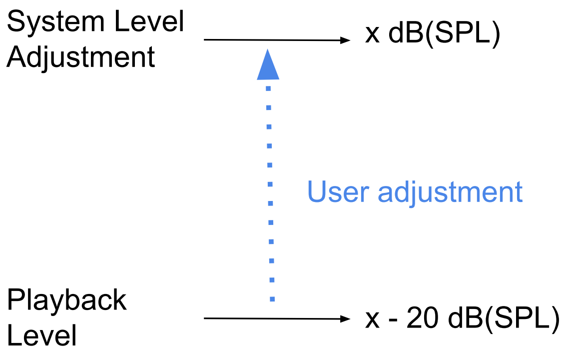


Fig: Listening Level testing paradigm

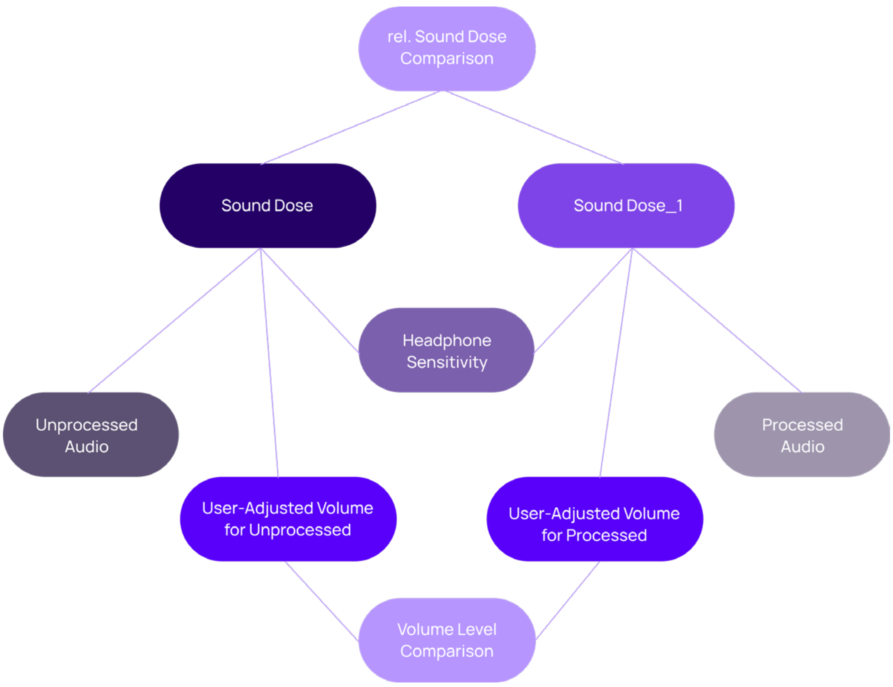
In theory, users should use the buttons in such a way that their original volume adjustment was achieved, meaning they would bridge the 20dB of difference. Our hypothesis was that this self-adjusted difference should be less for the cases in which audio files were personalized to the listeners hearing ability by processing them with our DSP accordingly.
The study was only designed in a bottom-up (move the volume upwards) design. This had two reasons: the first consideration was to simply prevent harming the participant's hearing by too loud sounds. Secondly, the study attempted to simulate a real life situation in which headphones are put on and the volume is adjusted to the preferences. It was hypothesized that a self-adjustment is more likely, when content is inaudible or too quiet and that there could be a tolerance to too loud sounds on the other side. However, in this study the attempt was not measuring the tolerance to loud sounds but the preferred listening level. Hence, a pure bottom-up approach was chosen.

Results

Data cleaning

As mentioned above, this study wants to shed light on two aspects: the volume level changes that users initiate between unprocessed and processed sound with Mimi processing and secondly, the sound dose differences these changes result in.
In the first step, volume changes were used to clean the data. While online studies are a powerful tool to generate research data, remote study data is often of lower quality than could be obtained during in-house studies. To clean data, we applied different plausibility criteria.

The first plausibility check was done by using a hidden reference approach in which the audio from the volume setup part was again presented in the beginning of the study and participants' adjustments had to somewhat line up with their initial setting. A second exclusion criteria was too little interquartile range between stimuli per user indicating when users were just skipping through without real adjustments. Lastly, to avoid ceiling effects, volume ratings per user in which the maximal volume was reached were excluded (all ratings per song and user). After data cleaning, 77 usable data sets remained.



Subsequently, data across and also within participants still looks more like a range than a certain level participants go back to. In the plot below, the 80 dB line represents the level at which the reference audio in the beginning of the study was presented. The 60 dB level represents the level of playback for all following stimuli. The initial assumption was that participants would move their volume back up to the 80 dB level to compensate for the artificial level decrease.

This task is essentially a most comfortable loudness task. Data shows that there is quite a range of most comfortable loudness, for different audio files. This finding is in line with other studies[2].

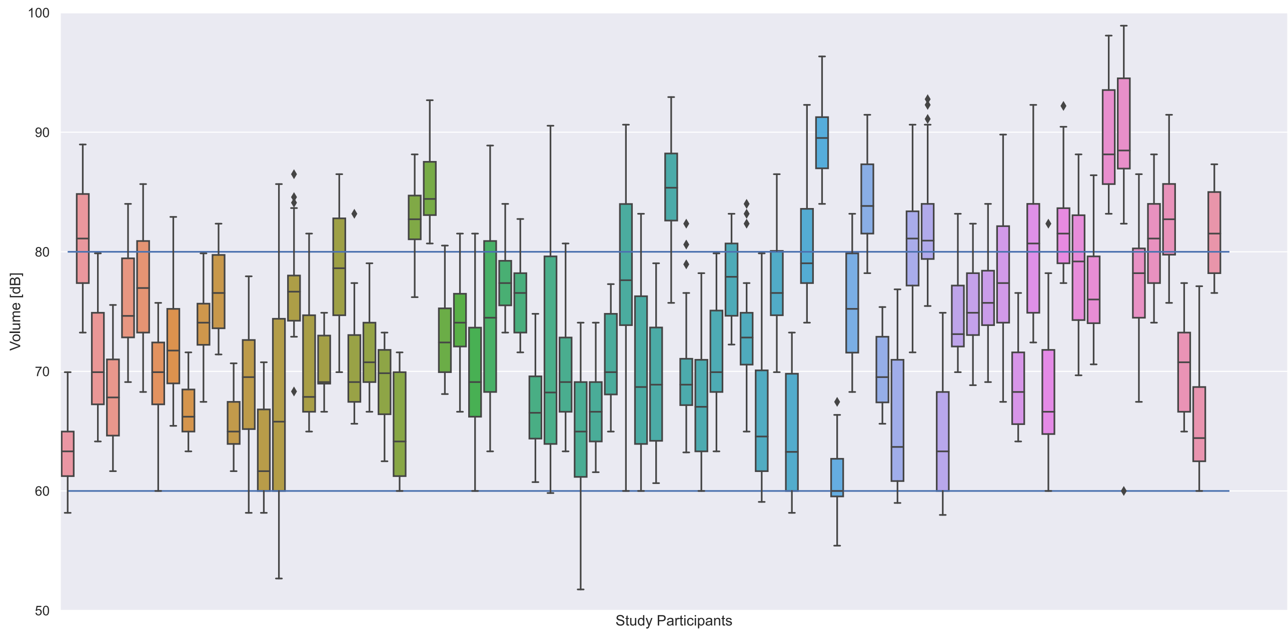


Fig: User volume adjustments pooled across the different sound stimuli per participant

[2] Punch, J., Joseph, A., Rakerd, B., 2004. Most Comfortable and Uncomfortable Loudness Levels: Six Decades of Research. Am J Audiol 13, 144–157. https://doi.org/10.1044/1059-0889(2004/019)

Answers to Questions

A small questionnaire was added in between, to give users a small break from repetitive audio listening tasks.The figures below show the most interesting answers for questions that were asked during the break. Generally people reported having no issues with performing the task.

The following key findings can be derived from the answers:

- Most people often reconsider a volume re-adjustment on their devices.
- Protection alone is not the reason for people to adjust - it has to be combined with listening pleasure or may even be purely motivated by listening pleasure.

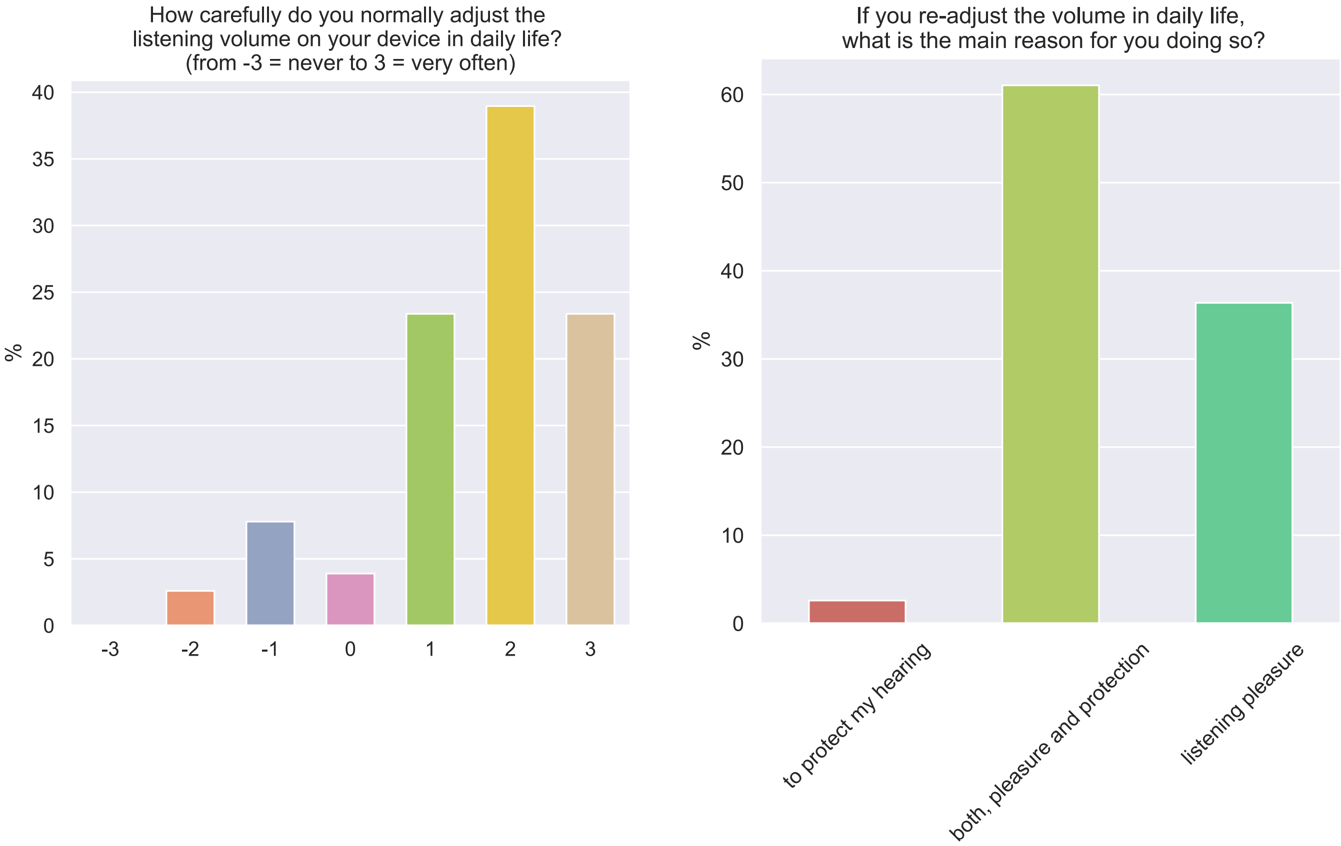


Fig: Insights about listening level adjustment

Volume and Sound Dose

Volume differences between personalized sound and the unprocessed condition across participants for different types of listening scenarios (audio files) is shown in the figure below. The plot illustrates that on average the listening volume with Mimi's processing is below the unprocessed version for all three groups of hearing abilities, including normal hearing. But as mentioned above, the focus should be on differences of actual sound exposure.

The figure below demonstrates that people receive less sound dose when listening to audio processed by Mimi in comparison to unprocessed sound. In different groups the median values range between -5% and -30%. The inter-subjective variation is quite strong, indicating that people's behavior is very individual. But on a participant level results suggest that the majority of people receive lower sound dose when listening to music with Mimi sound personalization.

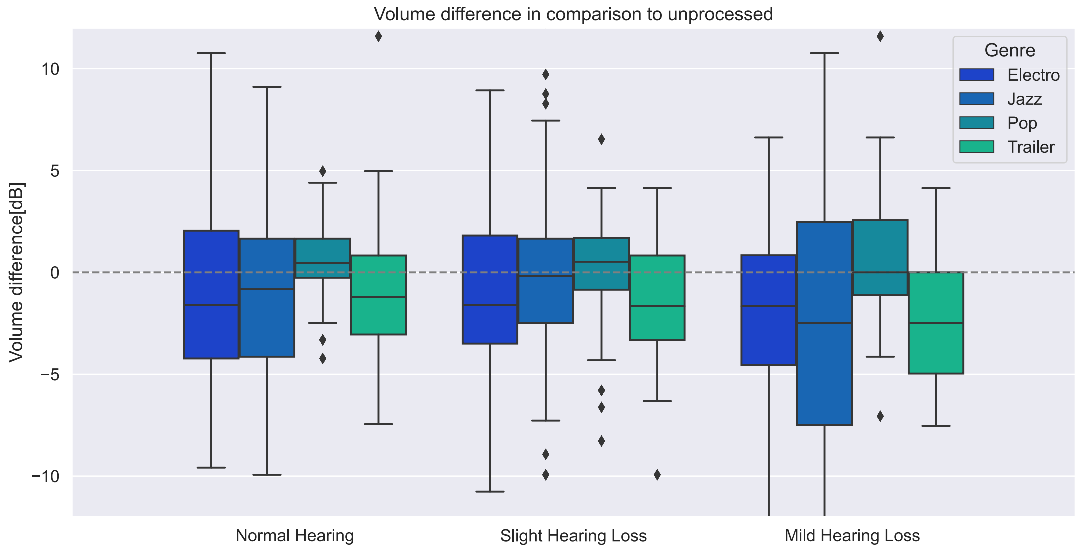


Fig: Volume difference against unprocessed

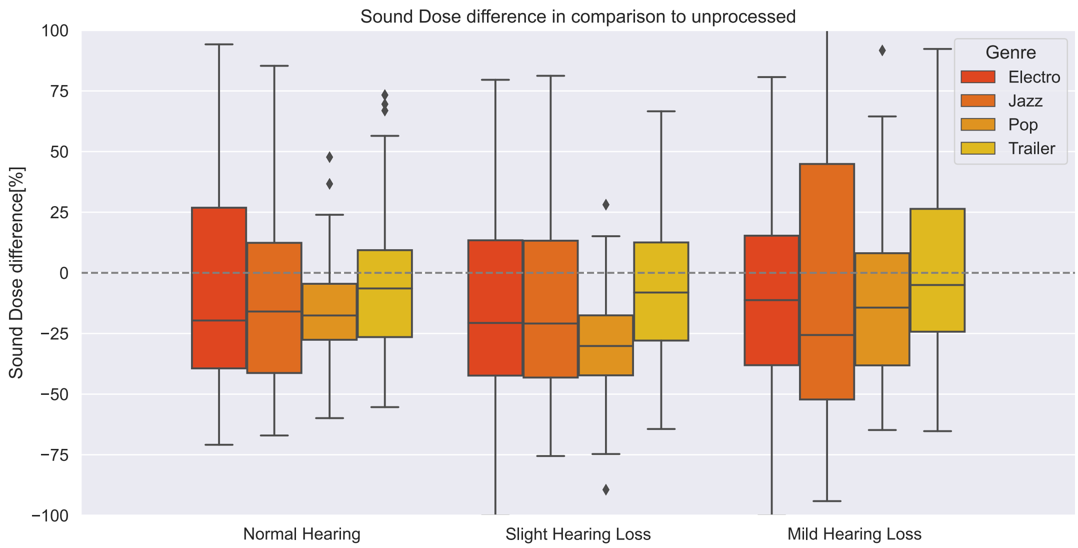


Fig: Sound dose difference against unprocessed

Conclusion and Summary

This study's aim was to examine whether people are effectively lowering their device's volume when listening to personalized sound provided by Mimi's complex hearing loss restoration paradigms. An online study was conducted and sound dose was calculated by incorporating listener's headphones into calculations. Results showed that for the majority of participants, self-adjusted volume levels are lower compared to unprocessed audio. More importantly, for the majority of listeners, the sound dose they receive when listening with Mimi's processing is considerably less in all hearing ability groups and with different musical stimuli (medians ranging between -5 and -30 %). This means that with Mimi, on average, people can listen to music 5% to 30% longer, depending on the person and the musical content. Across participants, stimuli and hearing ability groups, the observed median dose decrease is 18%.

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