TICKLE TUNER - HAPTIC SMARTPHONE COVER FOR COCHLEAR IMPLANT USERS' MUSICAL TRAINING

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ABSTRACT

Cochlear implants (CIs) allow hearing impaired individuals to understand speech with remarkable efficiency. On the other hand, they poorly perform in music perception. It may be possible to improve the music experience with the use of other senses such as touch. We present Tickle Tuner, a haptic feedback device suitable for musical training of CI users. The prototype is composed of two high-quality haptic actuators and an external Digital to Analogue Converter (DAC) hosted in a 3D printed enclosure coupled with a smartphone. We describe the design and implementation of the prototype, the analysis of its characteristics and we introduce a test bench for the design of different mappings between sound and vibrations.

1. DEMO DESCRIPTION

CIs are neuroprosthesis that allow people with severe or profound hearing loss to restore their sound perception. They are especially successful in reestablishing speech comprehension [1]. Music is a highly complex signal and, during the electrical stimulation of the auditory pathway, there are many factors that can influence CI users' access and fruition [2–4].In this demo we propose the Tickle Tuner, a vibrotactile feedback device that provides haptic information during musical training that can be performed using *ad hoc* mobile games. These applications are developed for improving CIs skills to better recognize musical features and thus increase music appreciation. The name of our prototype derives from the Tickle Talker, the first device that uses haptic feedback to aid speech understanding [5].

The smartphone cover has been 3D printed and is mainly composed by two parts: shell and handles. The shell features an adjustable rail system and a frame that holds in position the smartphone, hosts part of the cables and connects the two handles. These are the main contact area with the user's hands and are shaped in order to have a stable and comfortable grip. We initially shaped a handle's model using clay and then, thanks to photogrammetry, we obtained a 3D reconstruction. The Tickle Tuner features two HapCoil-One (Haptuator Mark II-D) actuators produced by Actronika [1] that can reproduce frequencies from 10 to 10000 Hz. They are both connected to a 3W stereo class-D amplifier PAM8403 chip on a DFR0119 board. The smartphone feeds the Haptuators through a digital to analog converter chip (DAC) that receives the audio stream through a USB-C plug. We slightly modified the DAC soldering two cables from the pin-out of the USB-C connector to retrieve DC (+5V) and ground (GND) for powering the amplifier. In this way, with a single plug the Tickle Tuner is able to retrieve the audio signal and the power recalling the *plug and play* concept.

In order to understand the acoustical characteristics of the Tickle Tuner, we measured its frequency response following the guidelines of Farina at al. [6]. We performed the measurements in an anechoic room using an analog accelerometer (Sparkfun ADXL335) on seven different areas of the device and recorded the vibrations from one single output axe of the accelerometer. The areas taken into account are: top, bottom and side of each handle and the center of the smartphone screen.

The impulse responses retrieved from the different locations are fairly similar and present some common characteristics such as a peak in the low range around 70 Hz and lower energy in the highest section of the spectra. The device provides robust low frequency vibrations and we expect that it will contribute to improve the perception of the lowest portion of the sound spectra in CIs users. In order to mitigate the unwanted resonances of our device, we designed two different filter banks: the first one is composed by 50 biquad filters to obtain 25 EQ points of the fourth order, The second one is an approximation of the first one formed of 7 biquad filters of the second order.

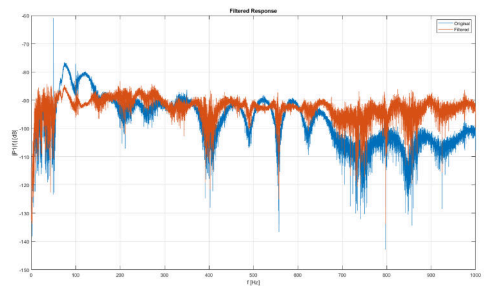

Figure 1. Comparison between the response of the Tickle Tuner with and without the 25 points EQ filtering.

Finally, we developed a third filter that compensates the

[1] https://www.actronika.com/, last access April 21, 2022

fingertips' sensibility attenuating the mid-low range of the spectra with a center frequency of 250 Hz [7].

In order to be able to implement different mappings of haptic stimulation, we designed a prototyping environment that generates different haptic cues. The program is still under development and features generation engines and real-time feature extraction from audio signals such as pitch and envelope of the first four partials. The test bench is capable of generating and reading sounds from the smartphone to quickly prototype directly with the Tickle Tuner. We chose to use a visual programming language called Pure Data [2] since is optimal for rapid prototyping and visual interaction. We also designed a Graphical User Interface (GUI) using the platform MobMuPlat [3] to have a comfortable access to the parameters from the touchscreen. Different mappings will be coupled to different types of sounds and will be tested on both normal hearing and CIs users during the oncoming part of the project in order to assess how haptics conveyed through this prototype can help in perceiving and creating a better understanding of musical features.

Figure 2. Front and back views of the Tickle Tuner.

Acknowledgments

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[2] `https://puredata.info/`, last access April 21, 2022
[3] `https://danieliglesia.com/mobmuplat/`, last access April 21, 2022