Characterizing perception of transcutaneous electrical stimulation on the external ear via psychometric functions

Research Summary

Tinnitus is a condition where one has the perception of a sound, such as ringing or hissing, despite the absence of an external auditory stimulus.[1] Tinnitus affects around 740 million people worldwide.[2] For some, this perceived sound can be irritating, decreasing their quality of life. Despite this, few effective treatments exist for tinnitus, launching research into developing new techniques.[3] Two new and promising treatment strategies are transcutaneous auricular vagus nerve stimulation (taVNS) and bimodal stimulation. Both have been shown to be effective, portable, and noninvasive.[4,5] Both treatment options make use of paired electrical stimulation (e-stim) and sounds to induce therapeutic neuromodulation that alleviates tinnitus symptoms.[5,6] A key element of e-stim is the intensity–the amount of stimulation delivered (referred to as e-stim level here). While there is a growing body of work on taVNS and bimodal stimulation, there remains no consensus on the optimal e-stim level for tinnitus treatment.

In this project, we aimed to understand the variability of the perceptual threshold of e-stim in tinnitus participants. E-stim was delivered by two electrodes, with the anode (positive) placed on the cymba concha, and the cathode (negative) placed on the ear lobe. After each stimulation, participants were asked to rate the intensity of each e-stim level presented in an ascending order from "not noticeable" to "extremely intense" (last panel in **Fig.1**). We measured participants' ratings to different e-stim levels across five separate days of testing. We then plotted the psychometric functions (**Fig.1**) estimated on each test day for all participants. We also measured the perceptual thresholds of the e-stim in the same rating procedure (rating = 1, barely noticeable). The measured thresholds are shown in **Fig. 2**. The data reported here will be used to understand the optimal e-stim level for taVNS treatment for tinnitus, which is being investigated in other ongoing studies in the TESSLab.

As seen in **Fig. 1**, the relationship between e-stim level and intensity for even a single participant is non-linear. Within one day of testing, participants can report decreases in intensity despite increases in e-stim level. Between days, a participant's rating of the same e-stim level can vary widely. Comparing between participants shows similar trends, as different participants had vastly different intensity ratings for the same e-stim value. Different participants also had

different perceptibility ranges, indicating that using a constant e-stim level could result in some participants not feeling anything at all, and some participants feeling uncomfortable.

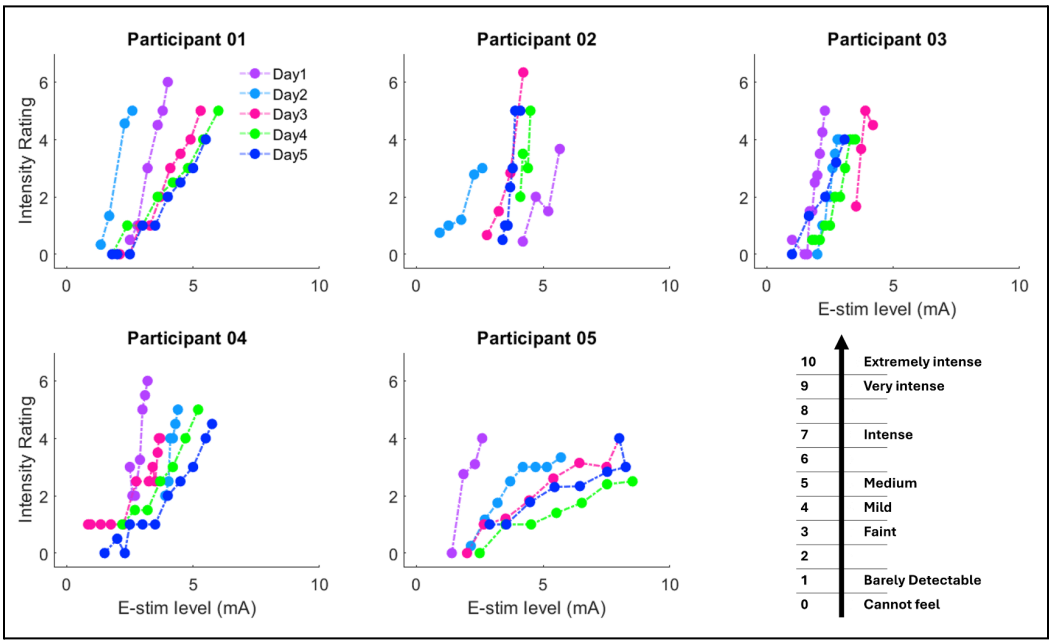

Fig. 1. Psychometric functions of mean e-stim levels and mean intensity ratings across five days of testing for five participants.

One common method of determining stimulation intensity is based on a participant's perceptual threshold: the lowest stimulation level a participant can feel. Our results show, as seen in **Fig. 2**, that participants individually had quite varied perceptual thresholds day-to-day, with no clear trend between participants.

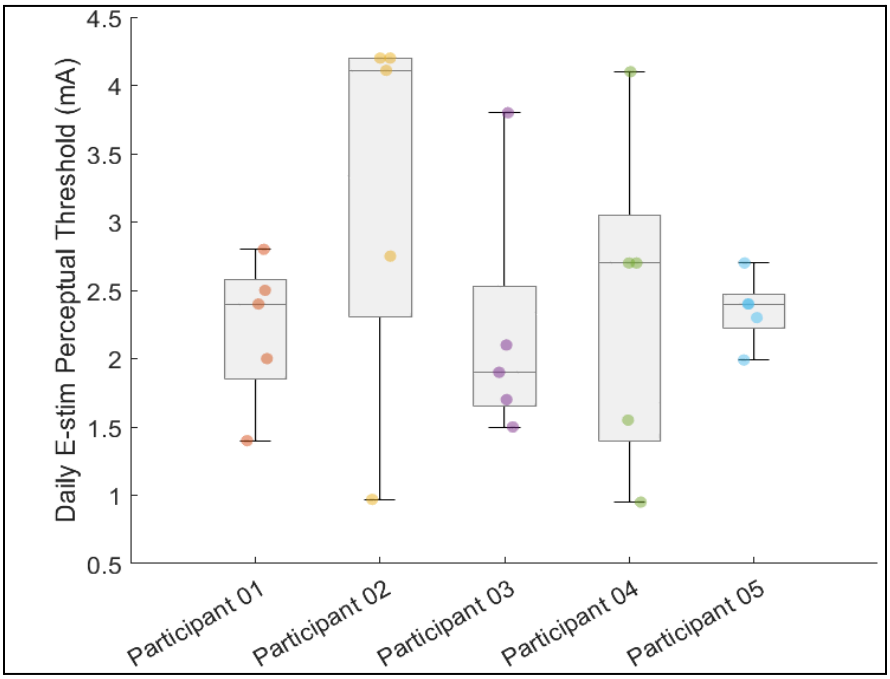

Fig.2. Box plots of mean e-stim perceptual thresholds for the same five tinnitus participants. Dots indicate perceptual threshold value for all five days for that participant.

The fields of taVNS and bimodal stimulation have the potential to give relief to millions of people with tinnitus. As such, it's important that a key parameter, like stimulation intensity and the process of deciding it, be standardized. Previously, many studies have simply picked one stimulation level and used it on all their participants. One review paper saw various taVNS studies using stimulation levels ranging from 1 to 10 mA.[7] Our data shows that this technique may be ignoring the immense perceptual variability that exists between participants. Thus, this technique should be reconsidered. Certain studies have attempted to rectify this by basing stimulation levels on perceptual thresholds, ranging from 0.5 mA above the perceptual threshold to 0.1 mA below the pain threshold.[7] Our results show that one participant's perceptual threshold can vary vastly between different testing days. As such, perceptual thresholds must be evaluated on a daily basis per participant to ensure proper stimulation levels.

UROP Evaluation

For this project, I wanted to better understand e-stim and how much variability exists between participants. This project certainly accomplished that objective, as it showed there is incredible perceptual variability that exists between humans. Having data that shows this can push researchers to take this variability into account in newer studies, which may improve the effects of e-stim treatment.

My Experience

This UROP was for Spring 2024, but I've had the opportunity to be involved in this work for nearly a year. During this project, we faced many challenges, such as ongoing construction, MATLAB code breaking, and all sorts of variability between participants. One of the largest challenges for me was learning to work with human participants. Closely interacting with participants, such as placing electrodes on their ear, was a new experience for me. Being able to work with Dr. Yuan He and PhD candidate Abby Heiller, both of whom helped me immensely on this project, allowed me to get through all of these challenges. Good communication allowed us to not only be efficient, but also gave me the confidence to ask questions about any part of the project. I'd like to thank the entire TESSLab for their support on this project and letting me learn about the incredible work and detail it requires to conduct research. I'd also like to thank the Office of Undergraduate Research for allowing me to engage in a research project of my own.

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