EEG Recordings Using Amplitude Modulated Tone, Noise, and Speech for Temporal Modulation Transfer Functions

Objective

The purpose of this project is to use psychophysical and EEG measurements to provide further evidence for the existence of broadband auditory filters for processing temporal information. Because of the limited EEG research devoted to auditory psychophysics; it is important to develop a more complete database for understanding how brain waves are affected by certain stimulus parameters, such as the rate of amplitude modulation. Consequently, this database will assist in choosing appropriate stimuli for future experiments designed to investigate the filtering properties of the auditory system.

Introduction

For numerous reasons, a better understanding of the underlying mechanisms involved in hearing would be extremely beneficial. One prominent aspect in auditory research focuses on perceptual processing of various stimuli, or more specifically, estimating internal auditory filter shapes, which would provide strong evidence for where and how certain sounds are perceived. Because auditory filters are a fundamental component of Auditory Theory, the ability to derive accurate estimates of auditory filter bandwidths has substantial implications for designing hearing aids and cochlear implants.

This notion of an internal filter came about in 1940, when Fletcher performed a band-narrowing experiment in which a band of noise centered at some frequency was used to mask a tonal signal located at the center frequency of the noise band. He hypothesized that some sort of internal filter is centered around the signal frequency and that the amount of masking is determined by the total power that gets through the internal filter. Under this assumption, broadband noise would produce the maximum amount of masking since a maximum amount of power could go through, whereas a narrow band of noise would provide less masking because less than maximum power would come through the filter. In other words, the signal would be harder to detect with a broadband noise masker and easier to detect with a narrow band noise masker. Fletcher called this internal filter the “critical band,” because frequency range within the passband of the internal filter is critical for masking. However, he found that when the bandwidth exceeds a critical band, thresholds are no longer affected by increasing the bandwidth of the noise. This critical band is thought to mark the edges of an auditory filter.

Fletcher’s theory of internal filters and the critical band was based on the assumption that detection of the tone was based on the total energy passed through an auditory filter. The development of ROEX filters was based on an axiom stemming from Fletcher’s work, in which detection relied on the total energy passed from an auditory filter. ROEX filters were also similar to Fletcher’s data, in that they both account for the output of only one channel. While these models may sufficiently explain a small set of data, various procedures were developed to test the importance of the energy cue for detection. Energy cues can be degraded with a roving-level procedure or equal-energy method and the results show that this has no effect of subjects’ performance. Thus, neither the Fletcher’s data, nor the ROEX theory are sufficient to account for the complexity of auditory processing, since they both rely on energy as the primary detection cue.

Both the ROEX theory and Fletcher’s data were focused on the spectral representation of auditory stimuli. However, spectral analysis cannot explain some perceptual events for certain sounds, such as the presence of beats or why a modulated sound is perceived differently than the same sound unmodulated. These events are proof that the auditory system uses temporal cues to discriminate sounds. Detection of modulated stimuli can be represented as a temporal modulation transfer function (TMTF). TMTF curves resemble wide, low-pass filters, which are more sensitive to low modulation frequencies rather than high. However, the need for a wide, low-pass filter for temporal processing contradicts the need for narrow filters for spectral processing. Thus, TMTFs are very important for understanding “temporal filters” in auditory perception.

Methodology and Approach

When an auditory stimulus is amplitude modulated at rates below 80 Hz, a spectral analysis of the EEG recordings will show a strong spectral component at the same frequency as the modulator. Typically, measurements have been made only at a few modulation rates which provide a good signal-noise ratio. In our experiment, we will collect finer grade data with modulation rates from 2 to 80 Hz, in 2 Hz steps.

Three passive listening tasks will use sinusoidally amplitude modulated tones and noise, and square-wave modulated speech. The stimulus will be presented for 30 seconds at each interval. Ten subjects will be given hearing tests and then they will be prepped for the EEG. They will go into the sound booth and EEG responses will be recorded. The listeners’ task is to listen and focus on the stimuli while staying awake. Prior to starting data collection, Matlab programs will be tested and run, and several test runs may be necessary to ensure the most effective stimuli configuration for evoking strong EEG responses.

Expected Results

After accounting for individual differences among subjects, the data should allow us to see correspondences between the behavioral TMTF and the TMTF obtained through the EEG. Data from speech stimuli compared to tone and noise is expected to be much stronger due to the human auditory system's extremely evolved sensitivity for speech detection.

Prior Work Completed

I have been working with my primary faculty mentor for close to 9 months now and I began working with my secondary mentor two months ago. We have already completed 2 EEG runs, one of which I participated as the subject. Preliminary data analysis has been completed for one of the two pilot runs.

Student Responsibilities

- Write Matlab Program
- Recruit 10 voluntary subjects
- Administer Audiogram hearing test
- Prep subject for EEG
- Setup and cleanup of EEG equipment
- Data collection
- Regularly meet with advisor
- Analyze data and formulate conclusions
- Write paper/ Prepare to present results

Timeline

April-May – Create Matlab Programs for all three stimuli; Meet with advisor at least once a week

May-June – EEG test runs, analyze data responses, alter stimuli; Begin recruiting subjects; Continue weekly meetings with advisor

June-July – Begin data collection from EEG; Have regular lab meetings to address any concerns

July-August – Finish collecting data; Begin data analysis on EEG recordings; Prepare for formal write-up of results

August-September – Complete final report; Discuss possible follow-up experiments

References

Viemeister, Neal F. (1979). Temporal modulation transfer functions based upon modulation thresholds. *Journal of the Acoustical Society of America 66(5)*, 1364-80.

Yost, William A. Fundamentals of Hearing: An Introduction. 4th ed. Elsevier Academic Press: San Diego 2000.

Yost, William A. and Stanley Sheft (1990). Temporal integration in amplitude modulation detection. *Journal of the Acoustical Society of America 88(2)*, 796-805.