**Localization of Acoustic Signals of Human Auditory System and Analysis of Neural Coding Using Cockroach Mechanosensory System**

**ABSTRACT**

In this lab we seek to analyze the different sensory responses to different vibrations and deduce how this effects the behavior of an organism. Using a dissected cockroach leg to mimick the mammalian auditory system, and a pair of headphones to create the illusion of a moving auditory stimulus. For the first part of the experiment, we impaled the cockroach leg onto a pair of electrodes, and applied mechanical vibrations of different frequencies to a single spine along the leg. We hypothesized that increasing the frequency of the stimulation would elicit higher frequency responses up to the dynamic range of the nerve. In the second part of the experiment we hypothesized that as we increased the % amplitude disparity we would see a linear increase in a human observer’s chances of choosing what side a sound is coming from. In the first experiment, we observed that stimulus was applied to the cockroach spine, the frequency response of the afferent axon did in fact increase, but only up to the dynamic range of the nerves. Any increase in frequency stimulation after a high frequency did not further increase the activity. In the second experiment, we found that although we were correct in saying that increasing the Inter-Aural amplitude disparity did increase the ability of a person’s ability to perceive sound lateralization, the data showed that at around a 15% disparity, a person will be able to almost 100% accurately correctly localize the sound. This means rather than a linear increase, we see a logarithmic increase.

**INTRODUCTION**

In this report, we discuss the response of sensory systems to different vibrations. For this, we relied on the cockroach sensory hairs as means of modelling a hair cells, as well as headphones to mimic different sound properties to test human hearing.

By recording from the cockroach sensory hairs, we are able to observe a system analogous to the mammalian auditory system. These mechanoreceptors, when stimulated, display frequency responses, which in turn provide us with models that can be used to measure the strength, frequency, and timing due to the applied stimulus.

Analyzing the frequency response of the cockroach mechanosensory system allows us to understand the limitations of the system and predict how this plays a role in the behavior of an organism in the real world. To determine the frequency responses, we applied a simple mechanical stimulus to single spines on the cockroach leg to record the response of the afferent axons.

To gather more insight into how organisms respond to vibrations, we tested human hearing to characterize how physical properties of sound affect how we localize sound. There are two components of sound waves that effect our ability to localize a sound source. The first is the ‘amplitude difference (inter-aural amplitude disparity).’ This is where sound waves entering one ear is louder or quieter than it is in the opposing ear. The other component is the ‘time of arrival (inter-aural time disparity),’ which refers to the point in time which one ear receives the sound stimuli in relation to the other ear. Both of these components add to our ability to localize sound; however, each component plays a larger role for a particular frequency range.

Using headphones, we manipulated the loudness and time delays of sound stimulation provided to the human test-subject. This created the illusion that the sound was originating in one place and moving in a particular direction. It was then up to the human subject to determine where the thought the sound was originating, and in which direction was it moving. We focused on recording information from manipulating the amplitude disparity and test how this would impact the subject’s perception of where the sound was.

**METHODS**

The methods used in this experiment can be found in the “Introduction to System and Behavioral Neurobiology” manual, under the sections titled “Week 4: A Quantative Analysis of Neural Coding Using the Cockroach Mechanosensory System,” and “Week 5: Localizing Acoustical Signals. “

**RESULTS**

The results of these experiments show that applying different vibrational stimuli elicit responses in the sensory system of organisms. In **Figure 1.a** we see that applying a vibration to the spine on the cockroach’s leg evokes spikes which phase lock to the peak of each cycle. We see that the nerve responded consistently in .05 second intervals throughout each second of the 10 trails, as shown in **Figure 1.b**. Increasing the vibrational frequency to 30Hz elicited responses from multiple axons (**Figure 2.a**). We see here that the axon producing the smaller spike (approx. 0.005V) fires more consistently than the axon that fired a spike of approx. 0.01V. If we look at the average spikes of the 10 trials in the PSTH (**Figure 2.b**), we see that the spiking occurs inconsistently, and not in consistent intervals. We increased the stimulus to apply a 40Hz vibration; and same as when we applied the 30Hz stimulus, we elicited responses from multiple afferent nerves, and the spiking remained inconsistent. Further increase in the frequency of the stimulation no longer elicited further increase in the response past this point.

The final experiment, **Figure 4**, showed that with a 600 Hz waveform, when the inter-aural amplitude disparity is increased, the higher the percent of choosing the correct location and directional movement of an auditory stimulus.

**DISCUSSION**

The results of the experiments showed that as we were correct in hypothesizing that increasing the frequency of the stimulus being applied to the spine, the greater the rate of spike production up to certain point. As shown in the results, as the frequency of the stimuli on the spine went from 20Hz to 30Hz or greater, there was more elicited activity; however, by 40Hz The frequency of the firing rate had reached the end of its’ dynamic range here because further increase in the frequency of the stimulation did not elicit further increase in response. This means that high frequency can reach a point at which a sensory system is not capable of eliciting further responses to accommodate the increasing stimuli. Having a dynamic range is important because it may allow a nerve cell to be capable of responding to a specific range of stimuli. Then once added to a pool of other cells with their own dynamic ranges, this provides the organism with the ability to act around a large range of different stimuli.

We were also incorrect in believing that as the percent amplitude disparity increased the subject’s chances of correctly choosing the directionality of a sound stimulus linearly increases. We failed to keep in mind that at a specific disparity between two stimuli, any further increase in that disparity does not result in a person’s correctness further increasing because they are already around 100% accurate. As we saw in the results shown in **Figure 4**, there is a non-linear regression indicating that as the % amplitude disparity increases, at the % disparities about 15%, the subject, with near 100% accuracy, pinpoint the location and directional movement of an auditory stimulus.

Had we continued this experiment, we would have tested the inter-aural time difference to determine whether ITDs or IIDs are dominant for particular frequency ranges. It is likely that we would find that localization of tones at lower frequencies would best be determined by ITDs; whereas, IIDs play a larger part in higher level frequencies (Sandel, Teas, Feddersen, & Jeffress 2005). This would mean, we were to increase the experimental waveform while testing the inter-aural intensity differences, we would likely see that at lower percent amplitude disparities, a person’s performance in finding localizing the auditory stimuli and its direction, would increase.

**CITATIONS**

Sandel, T. T. and Teas, D. C. and Feddersen, W. E. and Jeffress, L. A.(2005). *Localization of Sound from Single and Paired Sources.* Department of Psychology, The University of Texas, Austin, Texas.

Bosma, Perkel, Kennedy, Canfield, Hass, Sisneros, (2016). *Introduction to Systems and Behavioral Neurobiology*. Department of Neurobiology, University of Washington, Seattle, Wa.