Aditya Iyer
UG IISc
SR 12485

Assignment 1: Rate Coding and Adaptation

Introduction

A cockroach leg was dissected and baseline and stimulated action potentials were recorded to infer rate coding and adaptation.

Thre recordings were saved as a .wav audio file. MATLAB 2018b was used to analyse the file. Data corresponding to different treatments were extracted according to a timesheet and plotted. A threshold was identified to count spikes and appropriate bar plots were made. No statistical analysis has been done for the different treatments.

Later, the cockroach leg was also stimulated to the tune of 'We Will Rock You' by Queen. The leg seemed to twitch to the bass of the music. Perhaps only those sections were above a certain threshold to elicit activity.
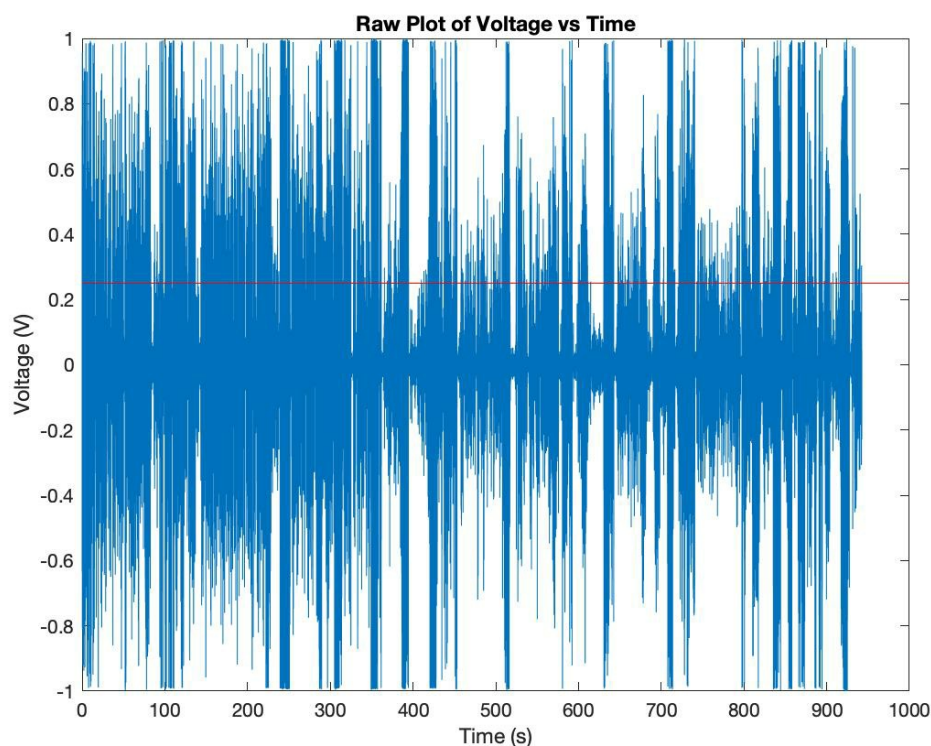

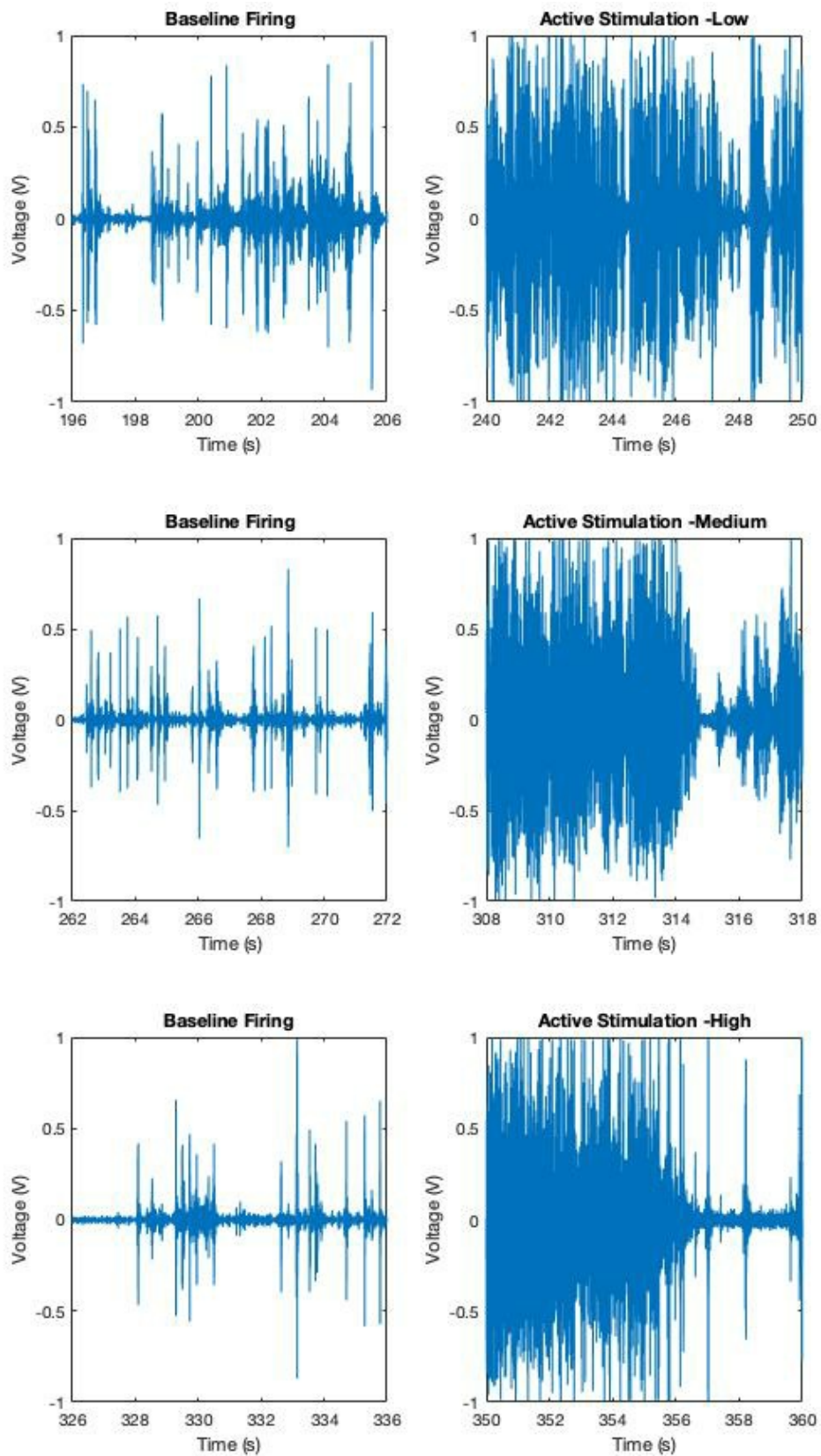Figure 1: Raw Plot of Extracellular Recording

Figure 2: Raw Data Plots for Baseline and Stimulation for different levels of stimulation
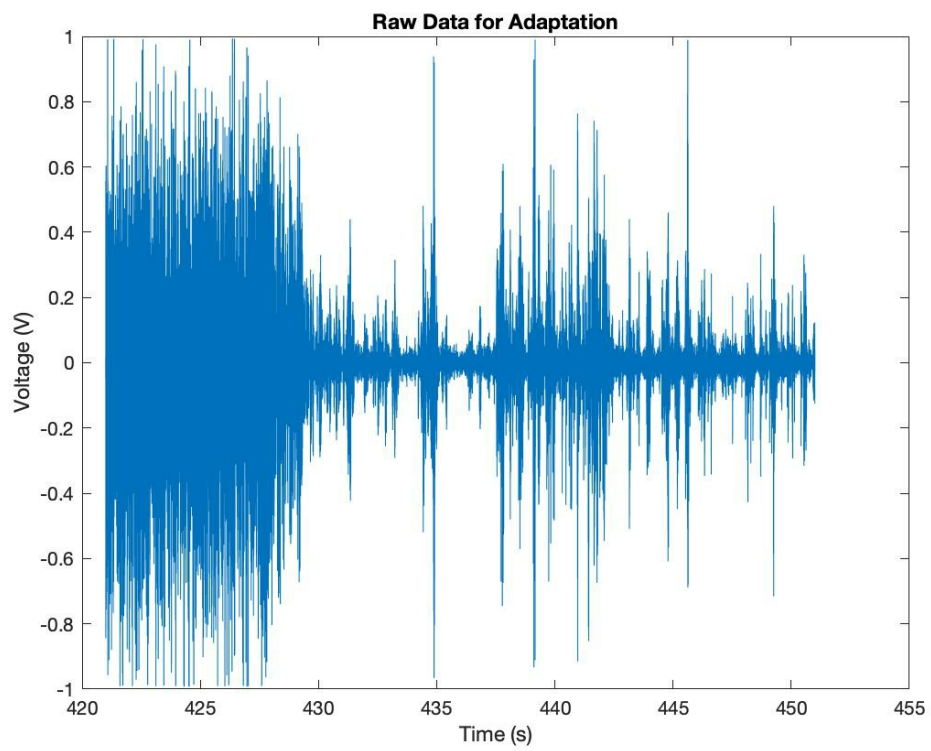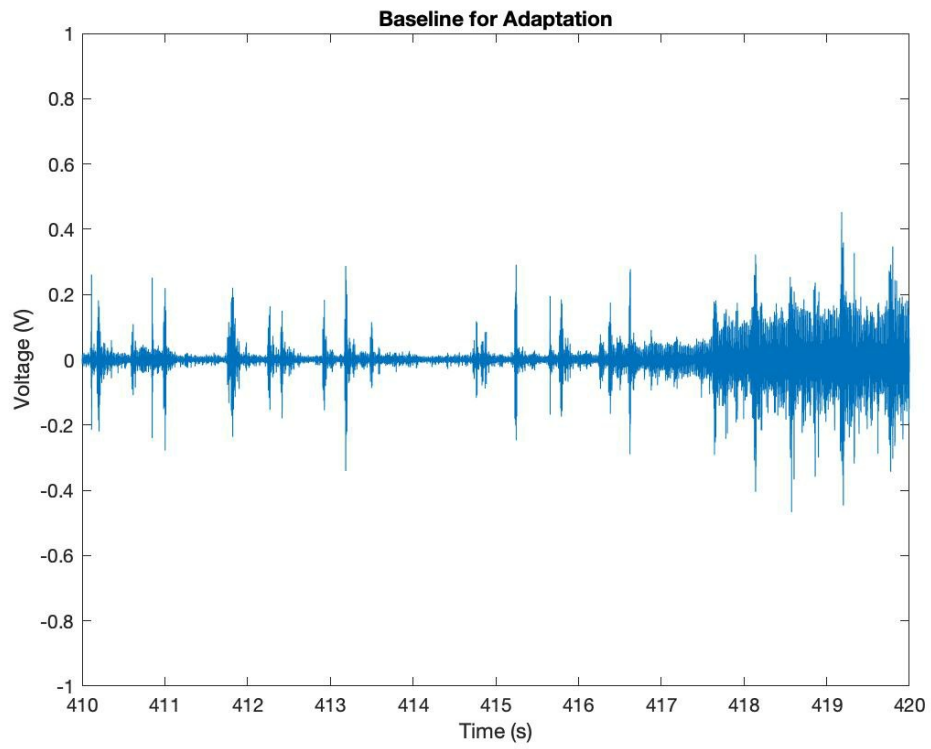
Figure 3: Raw Plots of Extracellular Recording for Adaptation

Questions

What happens if you choose threshold too low or too high?

Take a look at the figures showing baseline and stimulus response potentials (Figure 4). If we consider a threshold too low, there will be too many false positives, i.e. peaks that are not necessarily action potentials will be counted as spikes.

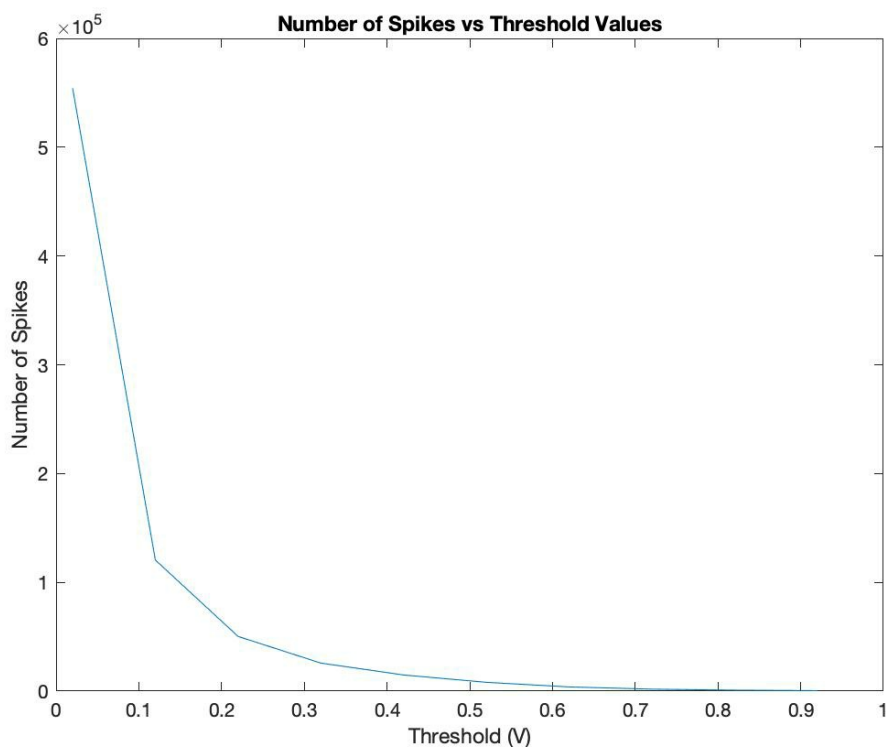If the threshold is too high, we could miss out on action potentials.

Figure 4: Decay of Number of detected spikes as threshold increases. See the rapid decline. At lower thresholds, a lot of noise is detected as signal.

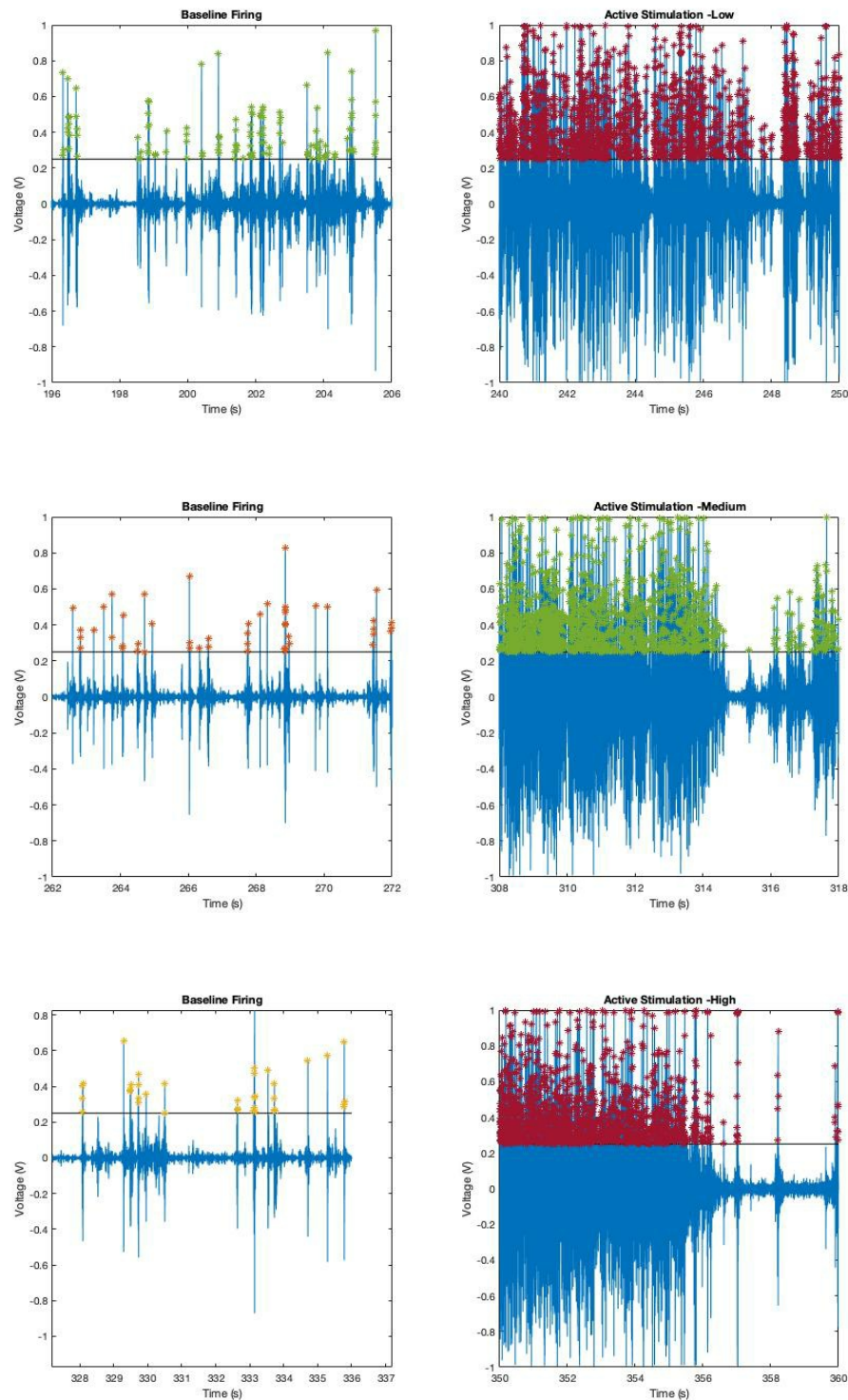Hence, a threshold of 0.25 was chosen.

Figure 5: Plots in Figure 2 with the threshold marked with a line and each individual spikes marked.

What happens to the firing rate as stimulus strength reduces?

As the stimulus strength is reduced, the firing rate is expected to reduce.
But, considering our threshold, we see the opposite, as indicated in Figure 6.
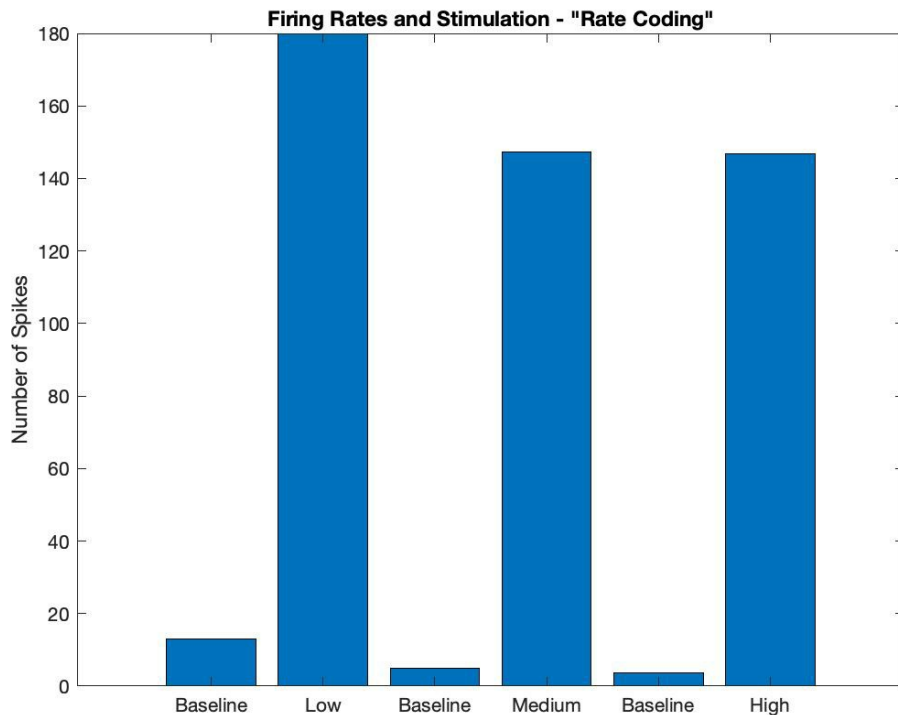
Figure 6: Bar plot for firing rates indicating rate coding. Note that there is a decrease in the frequency of spikes as the intensity of the stimulus increases

Why is it called rate coding?

The relationship between the strength of the stimulus and the spikes of evoked action potentials is called rate coding.

From the neuron's perspective, the strength of the stimulus is being translated to the frequency of spikes. In other words, the strength of the stimulus is being *coded* into the *rate* of spike firing. Hence, this relationship can be aptly called rate coding

Why do sensory systems need rate coding?

One of the objectives of a sensory system is to code external cues so that appropriate responses can be executed.

1. Responses are energetically expensive. If a sensory system were not able to differentiate the strength of a stimulus, responses to an external stimulus would be unnecessarily expensive.
2. Different strength of stimuli may require different kinds of responses. Rate coding can be used to switch to an appropriate response depending on the input stimulus. An example of this is muscle 'activation' at the arm on holding different weights at the palm.

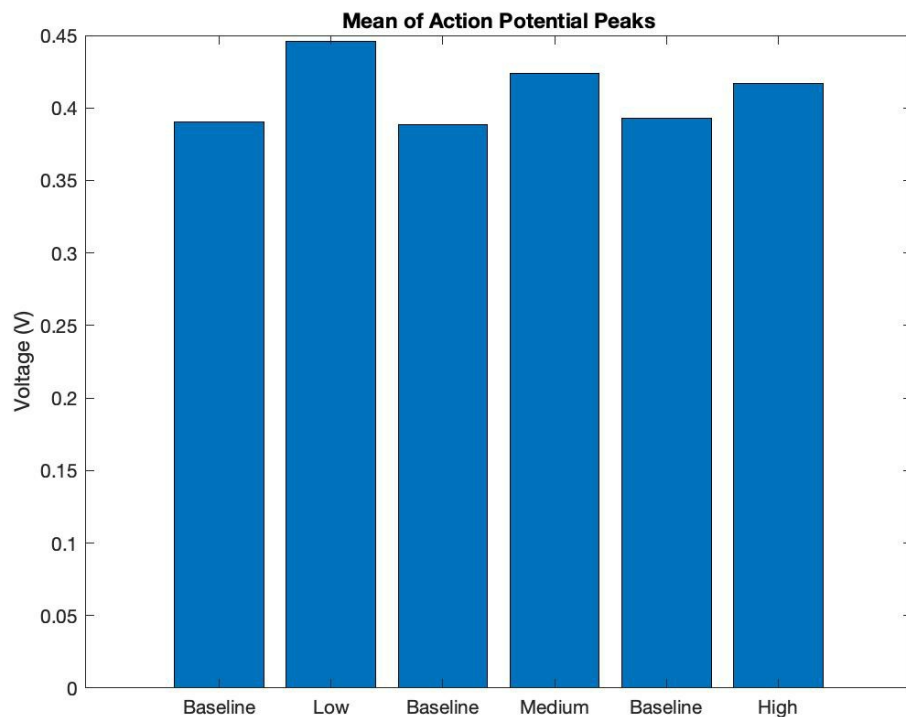# Is the mean amplitude same across baseline and stimulus? Why?

Figure 7: This bar plot shows the mean amplitudes across the baseline and stimuli for the three different stimulations provided.

Extracellular Potentials (ECP) are being recorded in this experiment. These Extracellular potentials are made up of the action potentials fired by neurons in the vicinity of the probe.

Each action potential spike amplitude is fixed. For the amplitude of the ECP to change, the number of neurons firing in the vicinity has to change.

As the mean remains almost invariant across treatments, it is possible that the number of neurons firing, i.e. coding for the mechanosensory stimulus remains the same independent of the strength of stimulus. Only the frequency of firing is modulated.

Adaptation

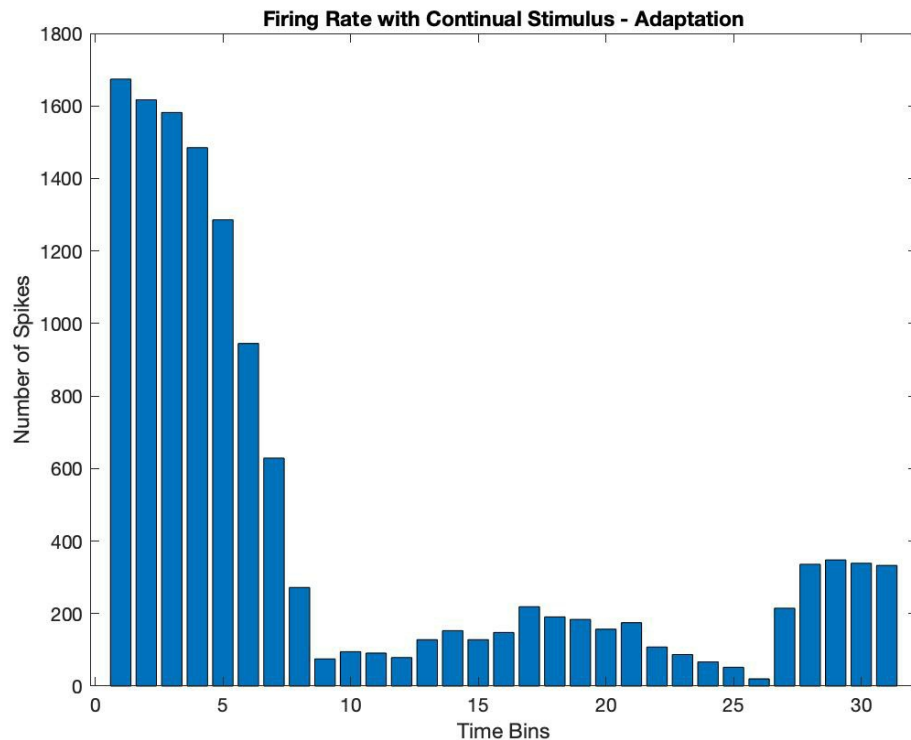## How does firing rate change with time?

Figure 8: Adaptation

As indicated in the plot, the firing rate reduces with time. This is consistent with the theory of adaptation, according to which, neurons should fire less frequently for stimuli that lasts for a long time.

What do you understand about the sensory system from adaptation?

Sensory systems would rather code changes in external cues than the absolute magnitude of the external cue.

A response is elicited by a change in an external cue or internal state. For a system that responds to changes, an absolute representation of the external cue is not necessary and would be a waste of computational power and energy.

Visualising the Waveform of an Extracellular Potential
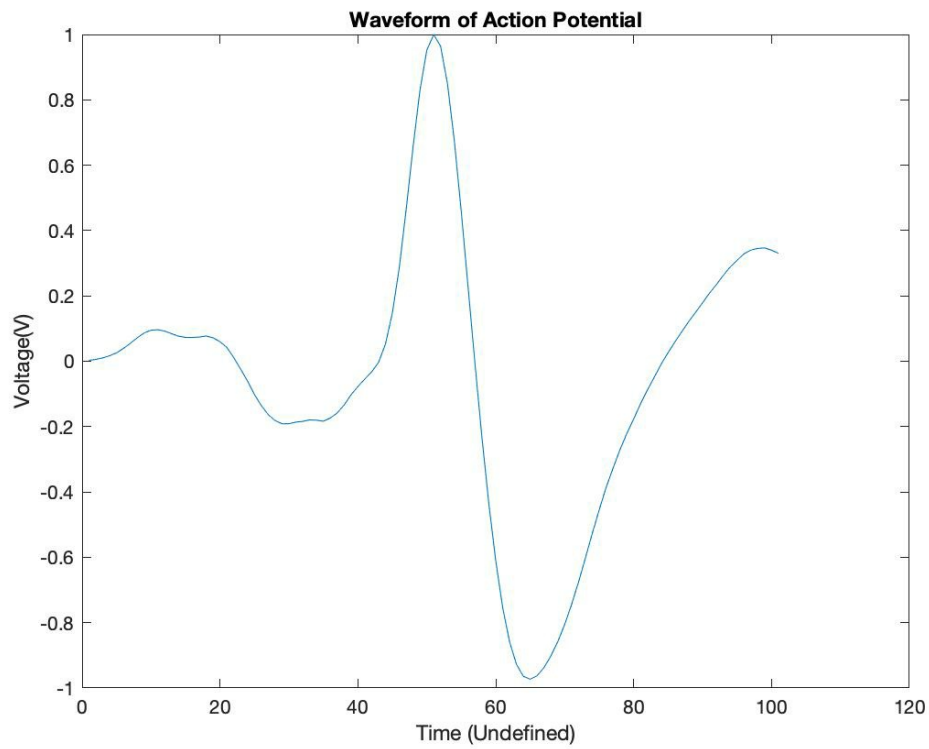
The recorded data about a spike (2.2 ms) is shown below.

Figure 9: Wave Form of Extracellular Potential