Predicting Learning-related Bevaviour of Mice using Interpretable Machine Learning

Sophie Fellenz, Jan Hirtz

June 2023

The research question we are interested in is "Which neurons in the auditory cortex of mice are responsible for learning-related recognition of specific sounds?" From the Machine Learning point of view, we want to look at how we can predict a mouses reaction during a learning paradigm from its brain activity. We also need to explain our prediction by showing which neurons specifically were responsible for predicting the mouse behaviour.

To answer these questions, we will analyze data recorded using calcium imaging in the auditory cortex of different mice (similar to the example shown in Figure 1) that are trained to fulfill a certain task. The calcium measurement is indicative of the neuronal activity produced in the brain. We will use time series data of the calcium indicator of several hundred different neurons that are spatially distributed across the deep layers of auditory cortex. From the calcium indicator we can also extract the spiking behaviour of neurons via deconvolution.

The objective of the thesis is to use machine learning to predict the mouse behaviour from this annotated data. In a second step we will look at different methods for making these predictions interpretable so that we can identify relevant patterns in the brain activity. Making deep learning methods more interpretable is an important research goal. For example, there exist methods to explain image classification results which highlight the parts of an image that have led to a certain prediction (e.g. is the classifier focusing on the dog's head or tail or just on the image background). In this project, we are interested in understanding which parts of the brain are responsible for making certain decisions.

What you can expect:

- An interesting interdisciplinary research project.
- The opportunity to apply your Machine Learning Knowledge to a new real-world problem that no one has applied Machine Learning on before.
- Gain experience with different deep learning techniques for processing spatiotemporal data.

What we are looking for:

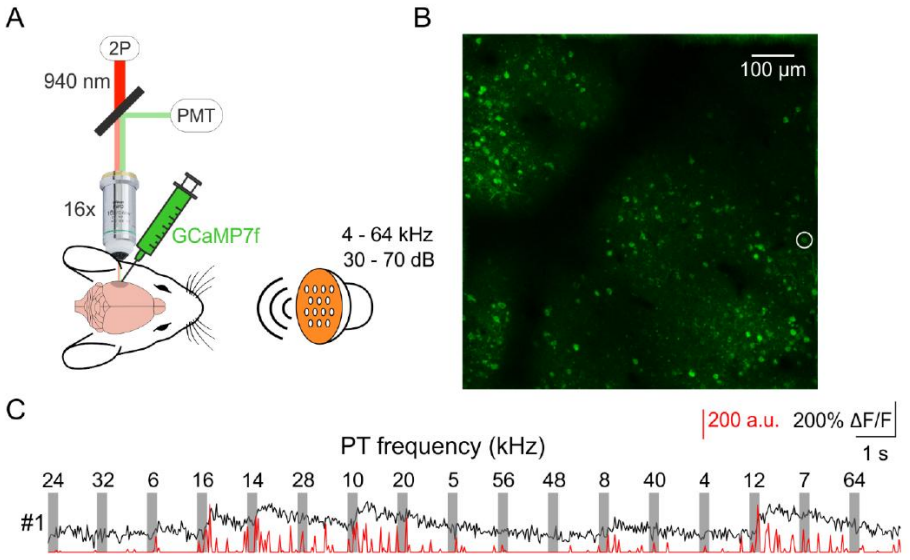

Figure 1: In vivo two-photon Ca2+ imaging in mouse auditory cortex during pure tone stimulation (A) Scheme depicting the principle of imaging activity of jGCaMP7f-expressing neurons during pure tone stimulation via two-photon imaging. (B) Maximal intensity projection of an activity time series, 230 μm below the pial surface. (C) Uncut extracted fluorescent activity (ΔF/F0, black trace) from the neuron encircled in B (white circle) and corresponding deconvolution (red trace) during pure tone presentation at 60 dB SPL. Timings and length (250 ms) of presented PTs are illustrated by grey bars with the corresponding frequency depicted above. Modified from Wadle, 2022 (Dissertation, RPTU)

- Familiarity with machine learning methods, in particular deep learning, and common frameworks such as pytorch.
- Interest in working on spatiotemporal data (almost like small videos).
- Interest in working on biological data, and communicate with Biologists if necessary.
- Ability to be goal-oriented and apply different methods independently.