Group Final Abstract

A perceptual decision-making task involves three steps : (i) processing sensory information, (ii) reward-based action selection, (iii) executing those actions [1][6]. The detection of novel stimuli is critical to learn and survive in a dynamic environment. In simple Go/NoGo decision tasks, the mice may act or not act for Go stimulus (resulting in a hit or miss) and NoGo stimulus (resulting in a false alarm or correct rejection) respectively, leading to four possible outcomes[1][3][5]. Here, we have analyzed the Allen Ophys Dataset [1][2] to study neural activities, behavioral patterns, and task outcomes associated with reward reception of mice performing a visual stimulus discrimination task. The mice may adopt various strategies to maximize reward-gain while performing this task as explored in [1]. The neural responses in the VISp and VISal regions, particularly the excitatory populations and inhibitory Sst and Vip neurons, correlate with these strategy adoptions. We aim to use GLMs to model the effects of behavioral strategies on the success rate of task performance by mice, as well as to understand the effects of these strategies on neural activity of different cell types. It is also quite possible that different mice have different preferences for strategy, and we want to investigate these preferences at individual mouse level, which may be decoded by neuronal activity.

A major methodological confound in these studies is the assumption that the mouse’s motivation levels, and by extensions the strategies it will employ when performing its choices, will remain the same throughout the experimental session as its hunger/thirst decreases [5], who segmented an experimental session where the mouse had to perform a binary task into three segments: early, middle and late. They showed that performance decreased across blocks which they attributed to the mouse becoming more satiated and not wanting to perform at a high level (motivation decrease). We explore if this lack of motivation is reflected in neuron cells such as the Vip and the Sst, expecting to see reduced activity when compared to the earlier times of a trial.

Neural correlates of sensory, behavioral and task information have been observed in mice performing such tasks, using for instance generalized linear model [2, 6. 7], with varied explained variance for different neurons. The reasons for such variable correlations of different neurons to sensory/behavioral/task variables remain elusive. **One hypothesis is that** **such neurons may have mixed selectivity** encoding multiple variables [8], which leads to diluted correlations for each variable. Since multiple neurons encoding the same variable appears redundant and inefficient from an information transmission perspective, **it is also likely that different neurons may encode the same variable as a population (population coding)**. To test these two hypotheses in a Go/NoGo decision tasks for mice [2], we sought to describe the statistics and dynamics of individual mixed neurons, as well as of multiple neurons encoding the same variable for the four different decision outcomes. We started by identifying the responsive neurons using the generalized linear model [7], and then used dimension reduction to the neuronal activities encoding the same variable. The reduced-dimensional neural activities allowed us to do dynamical system analysis at neuron population level, to understand how such population coding strategy influences the encoding accuracy of individual neurons and decoding of four decision outcomes. We then used the linear and nonlinear mixing model [8] as a “HOW” model to investigate the functional roles of mixed selective neurons performing complex decision tasks as in our study.

A limiting factor of this study is that it focuses only on three specific types of neurons to understand neural correlates. In particular, if we were to explore a more complex disinhibition effect of certain classes of inhibitory neurons, we would need to study a larger group of cells potentially leading to bigger and more complicated disinhibition circuits. A future direction could perhaps be this – experimentally study a bigger population of diverse cells and create normative models (RNN or STPNet, as shown in [4]) to understand disinhibition mechanisms in more details.

*[1] Piet A, Ponvert N, Ollerenshaw D, et al. Behavioral strategy shapes activation of the Vip-Sst disinhibitory circuit in visual cortex[J]. Neuron, 2024, 112(11): 1876-1890. E4.*

*[2]  Garrett M, Groblewski P, Piet A, et al. Stimulus novelty uncovers coding diversity in visual cortical circuits[J]. bioRxiv, 2023: 2023.02. 14.528085.*

*[3] Groblewski, P. A., Ollerenshaw, D. R., Kiggins, J. T., Garrett, M. E., Mochizuki, C., Casal, L., ... & Olsen, S. R. (2020). Characterization of learning, motivation, and visual perception in five transgenic mouse lines expressing GCaMP in distinct cell populations. Frontiers in Behavioral Neuroscience, 14, 104.*

*[4]**Hu, B., Garrett, M. E., Groblewski, P. A., Ollerenshaw, D. R., Shang, J., Roll, K., ... & Mihalas, S. (2021). Adaptation supports short-term memory in a visual change detection task. PLoS computational biology, 17(9), e1009246.*

*[5] Berditchevskaia, A., Cazé, R. D., & Schultz, S. R. (2016). Performance in a GO/NOGO perceptual task reflects a balance between impulsive and instrumental components of behavior. Scientific reports, 6(1), 27389.*

*[6] Steinmetz, N. A., Zatka-Haas, P., Carandini, M., & Harris, K. D. (2019). Distributed coding of choice, action and engagement across the mouse brain. Nature, 576(7786), 266-273.*

*[7] Park, I. M., Meister, M. L., Huk, A. C., & Pillow, J. W. (2014). Encoding and decoding in parietal cortex during sensorimotor decision-making. Nature neuroscience, 17(10), 1395-1403.*

*[8] Rigotti, M., Barak, O., Warden, M. R., Wang, X. J., Daw, N. D., Miller, E. K., & Fusi, S. (2013). The importance of mixed selectivity in complex cognitive tasks. Nature, 497(7451), 585-590.*