Assessing Anatomical Connectivity in Motor Cortex

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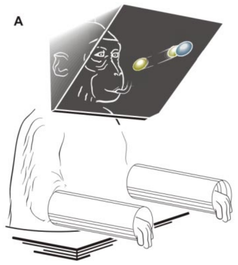
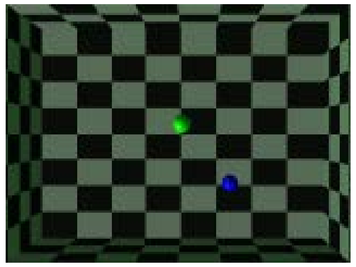
Motivation

- A neural network's computation is determined by its connectivity.
- However, anatomical connectivity is difficult to identify in extracellular recordings, since experiments usually do not last long enough to gather sufficient amounts of neural data.
- Here we leverage chronic multielectrode array recordings and techniques for tracking neurons over days to analyze anatomical connectivity in the motor cortex of Rhesus macaques.

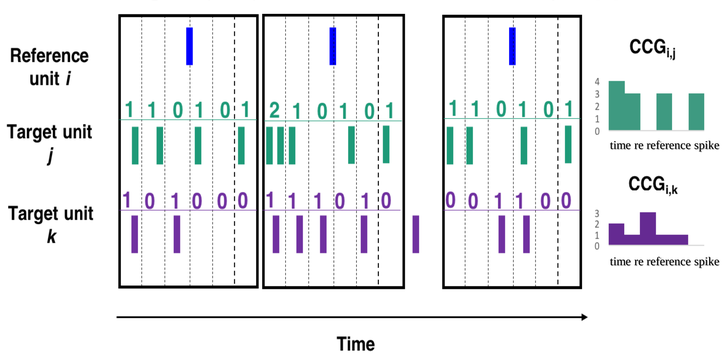
Method

- Two monkeys were trained to perform a 2D center-out cursor movement task using a brain-computer interface.
- Spiking trains of neurons were recorded while monkey performed the task. Activities of a subset of neurons were used to push the cursor [1]. We call these neurons "direct units", and the rest "indirect units".

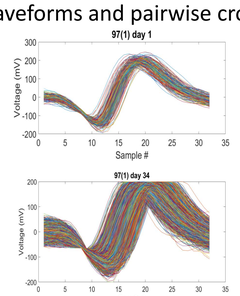


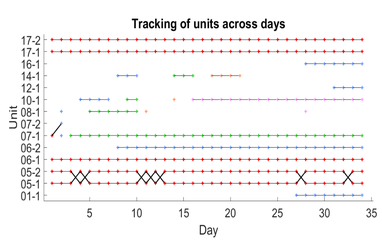


- Cross-correlogram (CCG) are constructed for each unit pair [2].



- Units are tracked between two consecutive days by investigating waveforms and pairwise cross-correlograms [2].



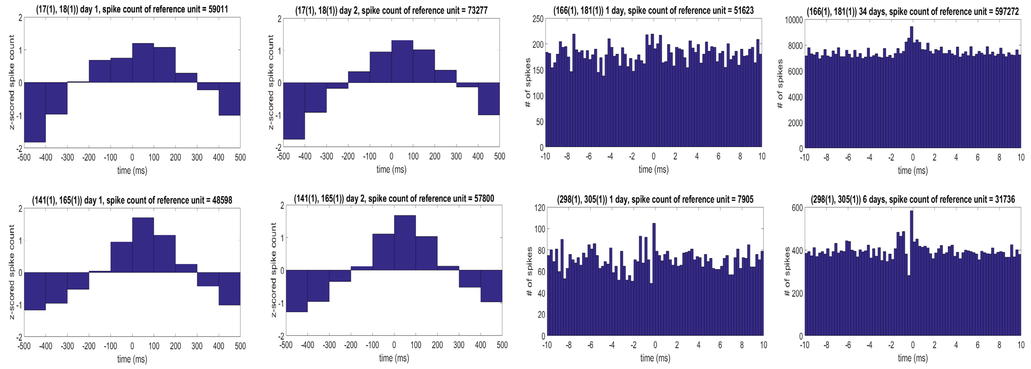


Results

- We analyzed a total of 15234 pairs across 205 units in two monkeys.

Pairwise CCGs with large timescale (100ms-binned) showing functional connectivity are used to track units between consecutive days. Three examples are shown here:

Pairwise CCGs with finer timescale (0.25ms-binned) are used to detect anatomical connectivity. These effects require a lot of data to reliably observe. Three interesting examples are shown here:



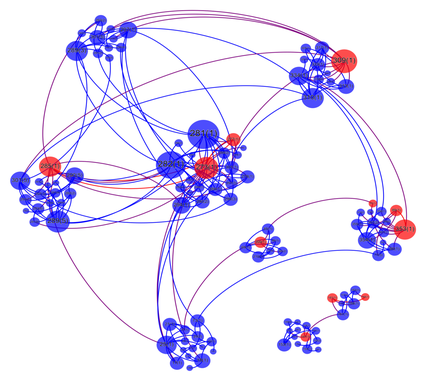
- Connectivity diagram:

Red denotes direct, blue denotes indirect.
Size of node reflects number of edges it has.

➢ 213 connections were found among 114 units: 11 direct units, 103 indirect units.

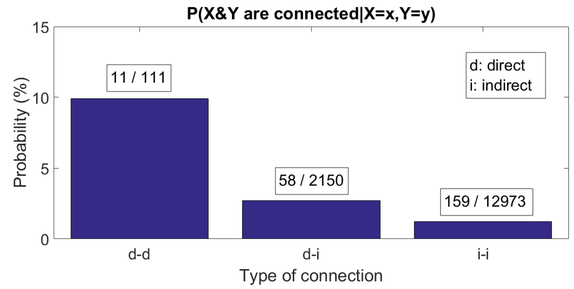
➢ Recorded units are shown to form sub-networks within which they are highly intra-connected.

➢ Units which are spatially close tend to lump together?



Analyses

- Probability of connection for pairs of different types implies that direct units are more likely to have anatomical connections among themselves.



- Connections are not randomly distributed among pairs:

➢ Simulation where pairs get equal chance of having connections vs. observed data:

Discussion

- Anatomical connectivity can be observed with sufficiently large neural data collected in long term experiment.
- Probability of having connections varies among direct and indirect cells.
- Future works include:

➢ Building rigorous scan test to assess certainty of pairs having connection from looking at CCG.

➢ Evaluate how angular difference in preferred directions of a pair of neurons correlates with its chance to be anatomically connected. Hypothesis is that neurons with comparable preferred directions tend to have connectivity.

Analyses

- Connections may change over time?

➢ CCG of a pair during first 17 days and last 17 days showing connection fading out :

Acknowledgment

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References

[1] *Jarosiewicz B, *Chase SM, Fraser GW, Velliste M, Kass RE, and Schwartz AB (*joint authorship), Functional network reorganization during learning in a brain-computer interface paradigm, PNAS 105:19486-19491 (2008).
[2] Ravikumar S. Tracking Chronically Recorded Neurons Using Pairwise Cross-correlograms [Master's thesis]. [Pittsburgh]: Carnegie Mellon University; 2017. 43 p.