Finding Reliable Activation of Neural Sequences in the Visual Cortex of Macaque Monkeys

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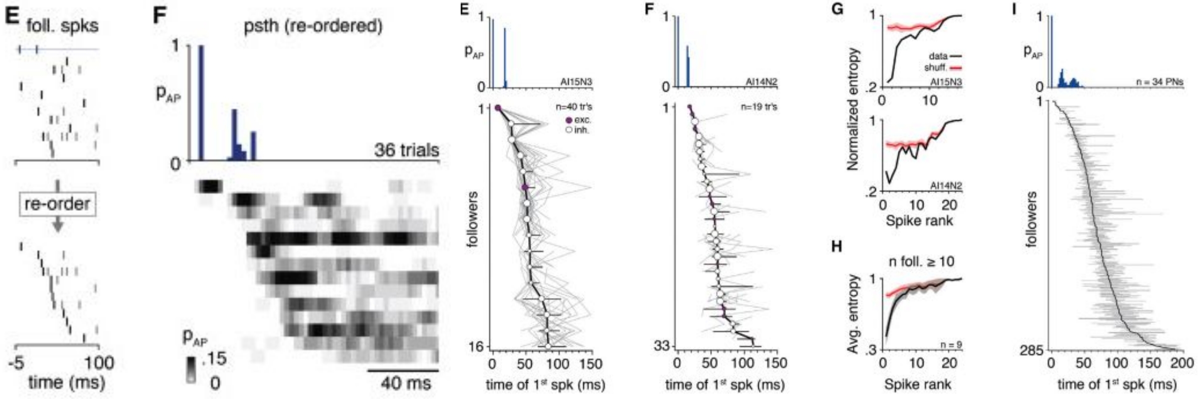
What is the result I sought out to replicate?

Authors stimulated single pyramidal neurons in the visual cortex of turtle brain slabs.

They identified distinct sequences of neural activation that occurs based on the pyramidal neuron that is stimulated.

They evaluated reliability of sequences by finding the normalized entropy of each sequence and comparing to an average shuffled entropy.

Identify Followers → **Find Response-Onset Time** → **Rank-Order Followers**



Entropy for k^{th} action potential across all followers: $E_k = -\Sigma P_i \log_2 P_i$

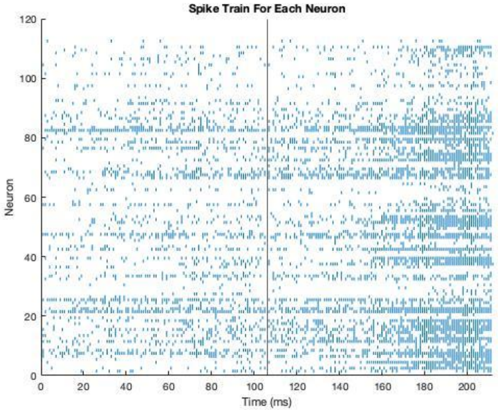
P_i = probability of follower i to be the k^{th} to fire.

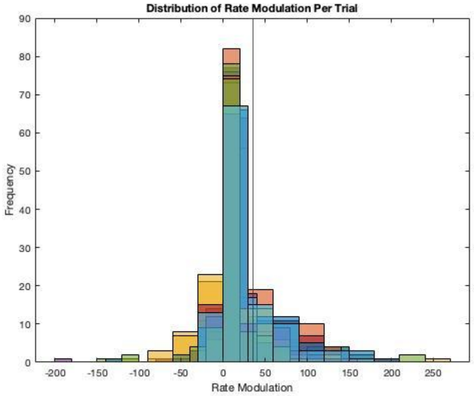
Divide by the entropy of a normal distribution resulting in a normalized entropy: $E_k = E_k \,/\, \Sigma\,(1/n)\log_2(1/n)$

Implementation

Use neural activity data from V1 of anesthetized macaque monkeys

- Monkeys are presented with an image for 106 ms
- 20 trials per image
- 956 images total





Identify Followers

Find neurons who increase firing rate by 1 standard deviation from baseline (106 ms period before stimulus presentation

Find Response-Onset Time

Identify time of first spike during each trial for identified followers.

Rank-Order Followers

Rank each follower by median response-onset time over all trials for an image

Controls: How did I validate my implementation?

Synthetic data created to replicate the authors' results

1. Pick *n* number of followers from normal distribution for 956 'images'.

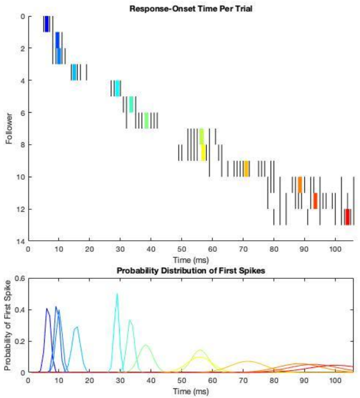
   μ = 15, σ = 5

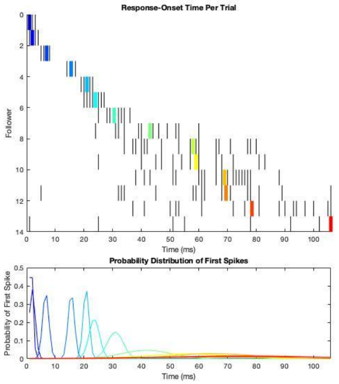
2. Pick *n* neurons at random from 120 neuron ids that are activated by an image.

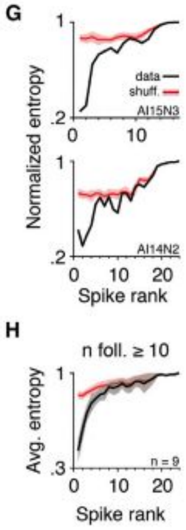
3. Create normal probability distributions of response-onset time for each neuron for the image.

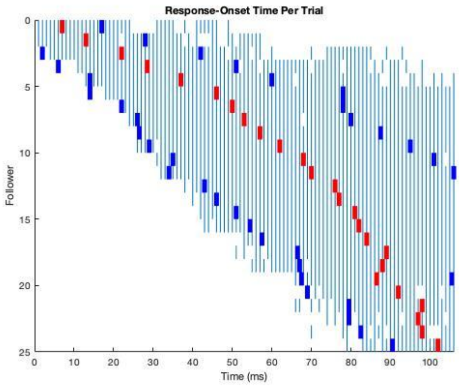
   μ = random number from uniform distribution between 1 and num_ms (106)

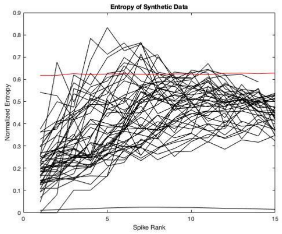
   σ increases as μ increases similar to data from paper



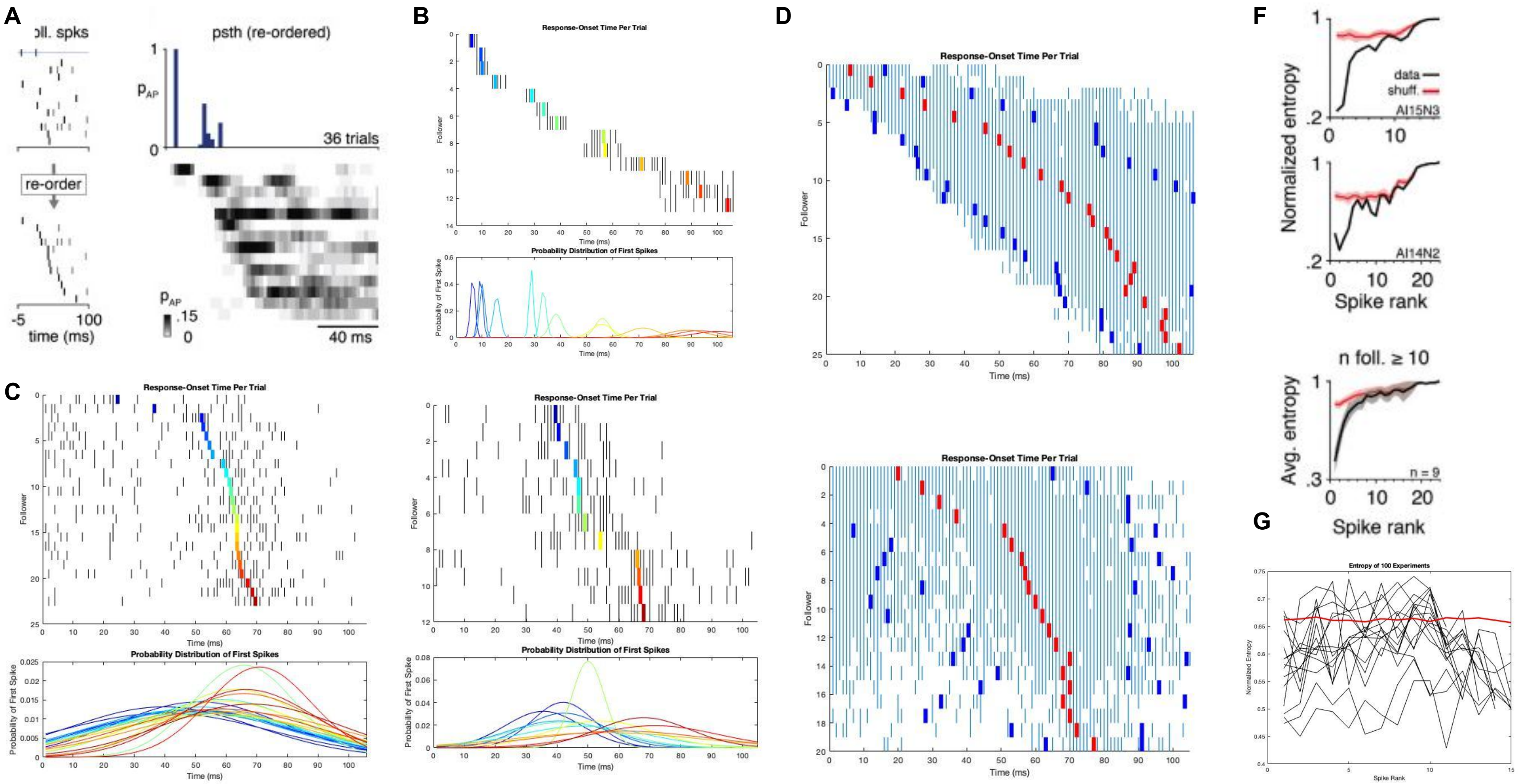








Replication



What unexpected challenges did I run into?

Rank Correlation

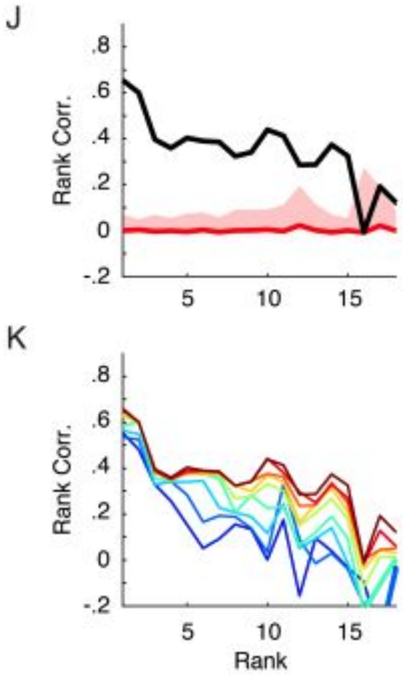
In the paper, the authors calculated rank correlation as another method to estimate how reliable sequences are.

1) For every trial k, calculate order matrix $O_k(i,j)$ for every neuron i, j pair. If onset time was:

$i < j, O_k(i,j) = 1$

$i = j, O_k(i,j) = 0$

$i > j, O_k(i,j) = -1$



2) Calculate order correlation matrix between trials k and l by multiplying the order matrices to get $O_{k,l}(i,j)$

3) To get similarity between trials, we average each column of $O_{k,l}(i,j)$ over all neurons that were active.

$$S_{k,l}(i) = \frac{1}{N_{active}} \sum_{i \neq j, j active} O_{k,l}(i,j)$$

4) Similarity between pairs of trials were averaged to get a rank correlation for each neuron.

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Conclusion

My attempted replication was not as successful as the paper because the identified sequences were not as reliable.

Based on the results of my attempted replication, the original paper's results seem difficult to replicate *in vivo*.

The turtle visual cortex was used in the original paper, but based on my results it does not translate well to the architecture of the visual cortex in mammals.

Lessons Learned

Ex vivo results may seem ideal and unrealistic when compared to *in vivo* results.

- There is much more entropy in vivo

Synthetic data is very useful for checking implementation of methods.

Learning and working with the format of publicly available neural datasets.