Neural Circuit Model for Chorus Frog Mating Behavior

Skyler Haas and Dr. Alan Lemmon

Abstract:

We currently know very little about how alterations in neural circuits translate to changes in behavior. The upland chorus frog (Pseudacris feriarum) is a prime subject for advancing our knowledge in this realm because their mating behaviors (consisting of male advertisement calls and female preferences for those calls) vary across populations.

We seek to identify the connection between neural circuits and mating behavior, focusing on the variables that are most likely to result in evolution. To do so, we fit neural circuit models to the behavioral data gathered from presenting alternative mating calls to female frogs testing and noting which calls attract the most females. This study was conducted in two populations that are known to differ substantially in their behaviors, an Alabama population and a Florida population.

In the end, my project hopes to find the evolutionary trajectory in neural circuit parameter space that allowed divergent evolution between these two populations. Specifically, I want to determine which neural circuits components have evolved. Additionally, I also hope to predict how female hybrids between these populations would behave when mating.

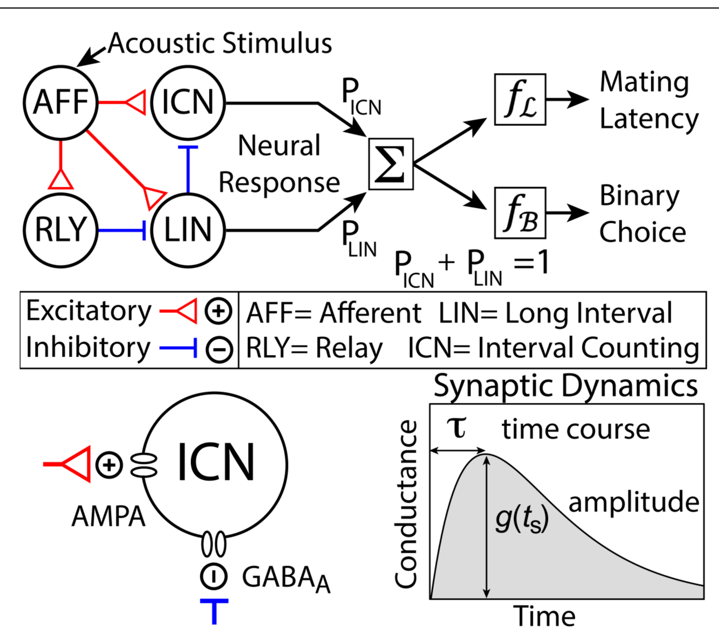


Fig. 1. Neural Circuit Model

Methods:

We conducted on a total of four chorus frog populations, which include two ancestral and two reinforced populations to look for neural circuit parameter combinations that demonstrate female preference. This poster will be focusing on the ancestral Alabama and reinforced Florida populations.

With each population as separate, we started from random points in parameter space within previously identified bounds.
We then utilized Particle Swarm Optimization (PSO) to discover good parameter values (peaks). We did not direct movement globally, relying on neighboring individuals to cooperate during the search. Subgroups were expected to find different peaks.

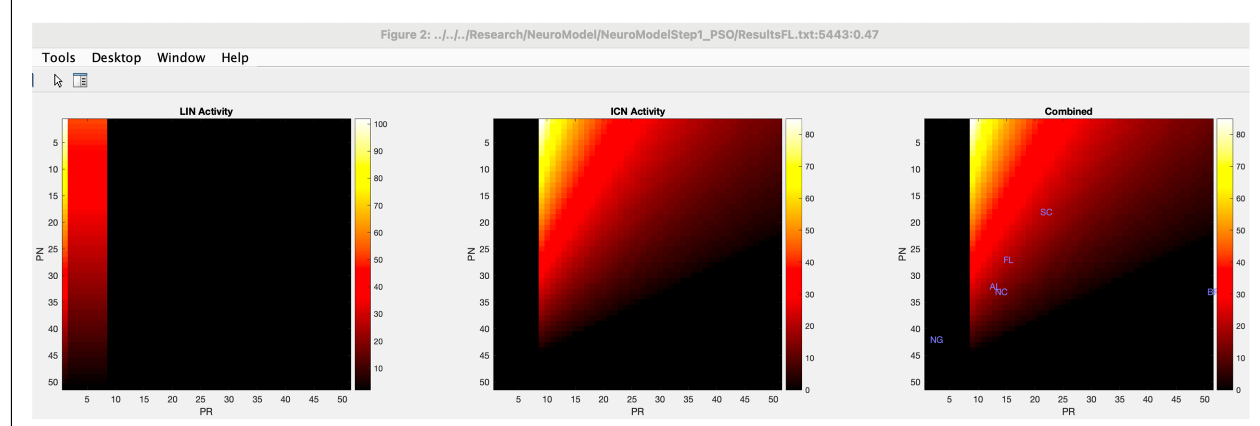
Following this, we created plots in order to
1) identify the optimal score and compare it to previous searches
2) determined how consistently peaks were found
3) identified the number of peaks for each population,
4) determined which parameters are the most important in allowing preferences to diverge among the four populations. Each plot is meant a different measure in identifying peaks.

In the last step we identified four circuit parameters that determine strongly how the model fits the behavioral data from the four populations: LINi_Tau, ICNe_Gain, and pICN, and ICNe_Tau.

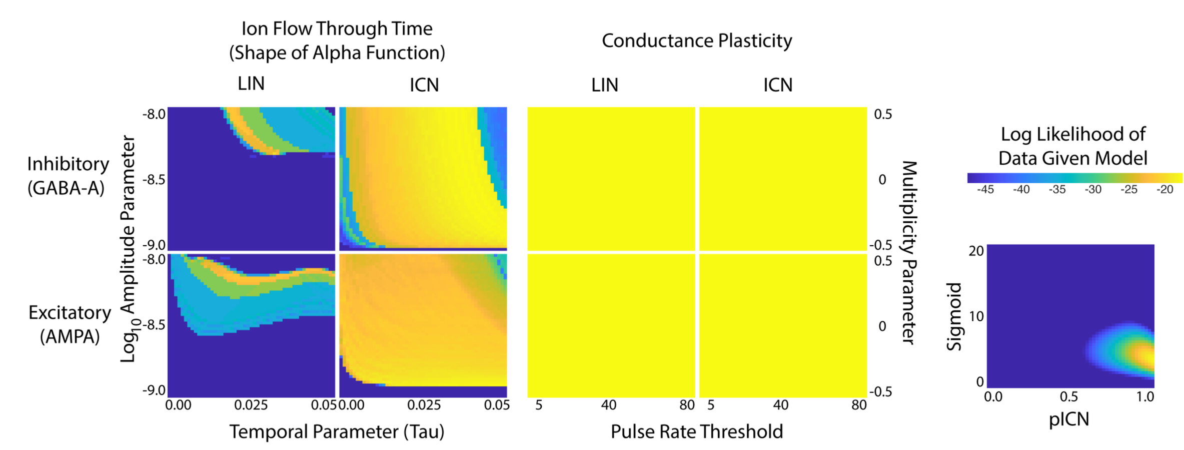
We will use a script to simulate spike counts corresponding to 501 values for three of the parameters (LINi_Tau, ICNe_Gain, and ICNe_Tau) in combination. The script takes in a parameter setting file that specifies the values fixed parameters are to take and also identifies which parameters are to vary, with one row per parameter.

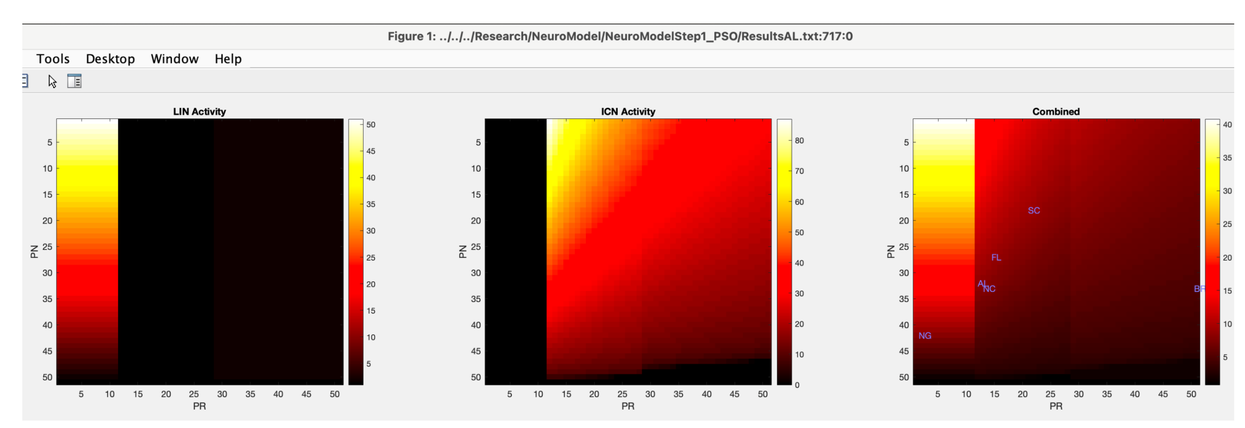
We will need to write a function that will take an output file and compute the likelihoods of observing the binary choice result for a given population. The sigmoid parameter will need to be optimized each time (low number would be more random preference and high number would have neurons quickly recognize changes in calls).

Results:

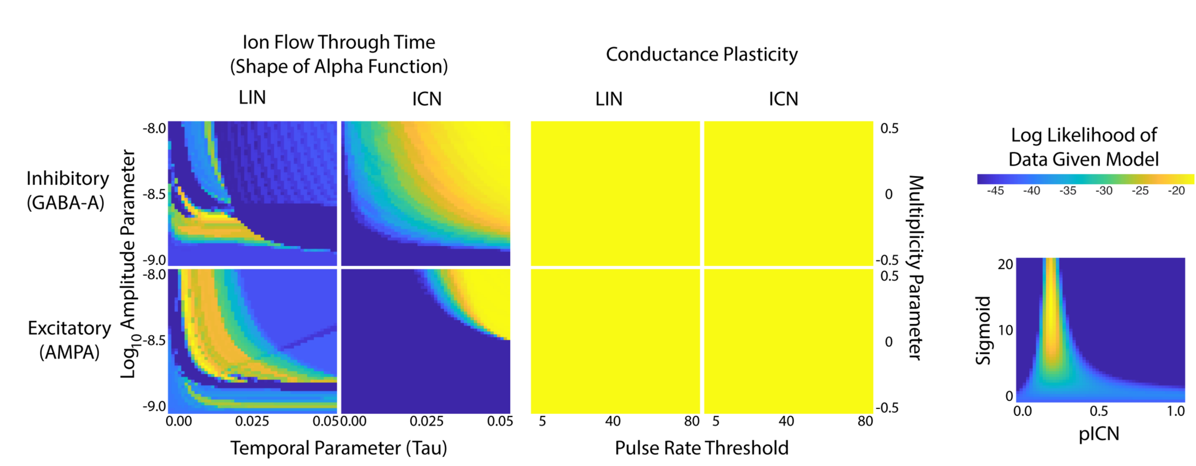


Florida Neural Activity Maps (Fig. 2, 3)





Alabama Neural Activity Maps (Fig. 4, 5)



Discussion and Conclusion:

The neural circuit is meant to imitate female preference and show how it can evolve. In the circuit, each neuron receives excitatory (AMPA) signals and if these overcomes inhibitory (GABA) signal the neuron fires. The signals are activated by auditory traits such as pulse number and pulse rate.

The model circuit is always finely tuned to the specific population, with different model parameters based on behavioral data. This is because of sharp boundaries in parameter space. View the Shape of Alpha Function in Figure 3 and see that the optimal neural circuit parameter value in yellow is incredibly close to the random preference values in dark blue.

Main Points:

Note that Alabama's population lives where there is no danger of hybridization, while Florida is home to one other species, *P. nigrita*. Neural activity for female preference in the Florida frog population has come to a point where it ignores LIN solely to shut down *nigrita*'s viability in mating. In the Log Likelihood map on Figure 3, see how females in Florida tend to use ICN receptors to a degree of 100% (in turn, the use of the LIN receptor would be turned down towards 0%).

This contrasts with the neural activity of Alabama's population, where there is a much lesser reliance on ICN. If there were *nigrita* to contact with Alabama's population, it is very possible they would be viable for mating. However, this is not the reality, therefore explaining the focus on LIN which can be seen in the Log Likelihood map on Figure 5.

We used about 1,000 tests of female preference from previous years to build our neural circuit, and our newer preference testing data will be used as time goes on and we do more ambitious mapping for our neural circuit. We hope to fill out areas in parameter space that have not been accounted for in the future.

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References

Lemmon, E. M. (2009). Diversification of conspecific signals in sympatry: Geographic overlap drives multidimensional reproductive character displacement in frogs. *Evolution*, *63*(5), 1155–1170. https://doi.org/10.1111/j.1558-5646.2009.00650.x