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Decoding The Neural Circuitry of Reward Behavior

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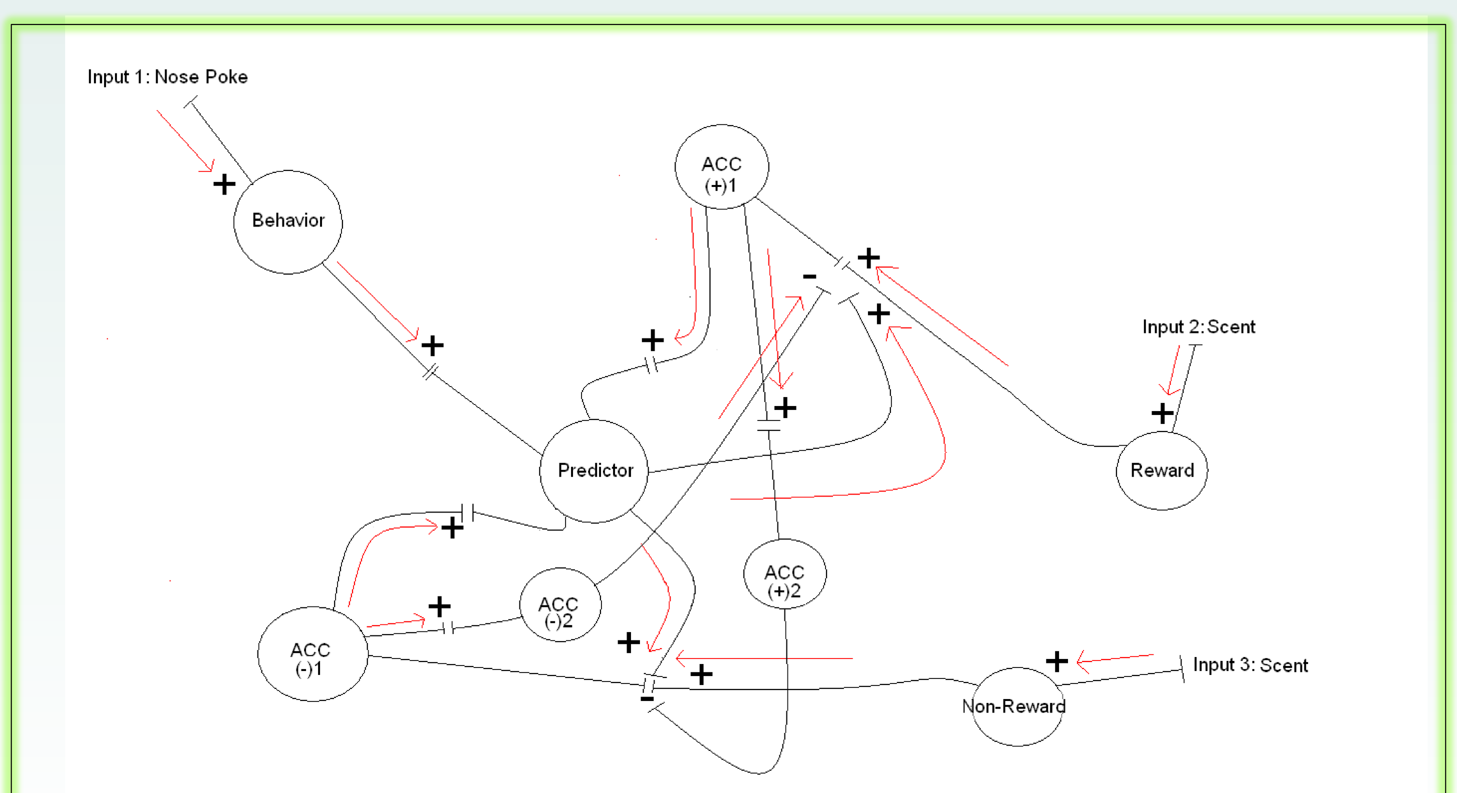
Introduction

Classical conditioning demonstrates that rewards can be used to train behavior by pairing a stimulus, known as a prompt, with reinforced behavior. At a neuronal level, this association strengthens the connections between the neurons involved, making communication easier the next time. Enhanced communication is identified with learning, allowing an organism to anticipate a reward with a prompt so that it can perform the desired behavior to successfully obtain the reward (Noonan et al., 2011). In this study, we created a computational model to represent a neural circuit with synaptic plasticity during reward, no-reward and anticipation states. Our results confirmed our hypothesis that the model would be able to differentiate between reward and no-reward stimuli and subsequently anticipate the likelihood of reward and no-reward states on ensuing trials.

Methods

Using the Neuron software developed by professors at Yale and Duke Universities, a computational model of 8 neurons was created to represent a neural circuit in the anterior cingulate cortex (ACC). The neural pathway follows the arrows in the figure below.



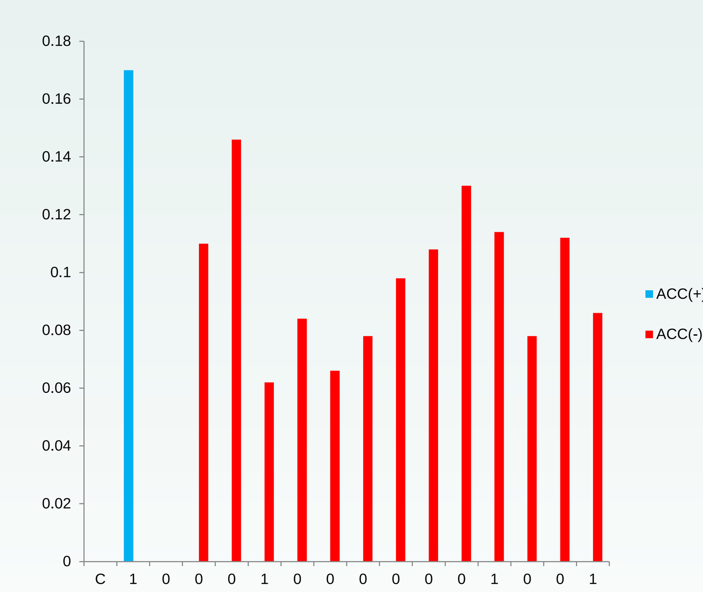
- The circuit received 3 input signals:
  - A reward stimulus that simulated a feedback scent 100% predictive of a reward (reward trial)
  - A no-reward stimulus that simulated a feedback scent 100% predictive of no reward (no-reward trial)
  - A prompt for a prediction that simulated a visual cue indicating that a reward might be available at the nose port (behavior trial)
- The simulation consisted of 31 trials, each separated by 1 second
- ACC(+/-)1 action potential amplitude peaks and time of peaks were collected only during behavior trails: during the control trial (C); after a reward trial (1); after a no-reward trial (0).

Results

The data were examined to note the differences in action potential amplitude peaks and peak times between ACC(+) 1 and ACC(-)1. A correlation was found between these attributes and the predictability of this model.

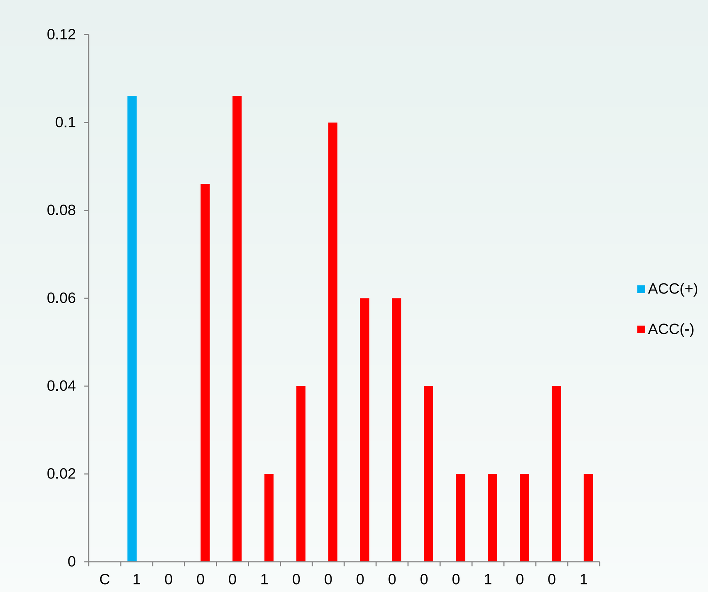
Action Potential Peak Differences

- A higher amplitude correlates with the anticipated state



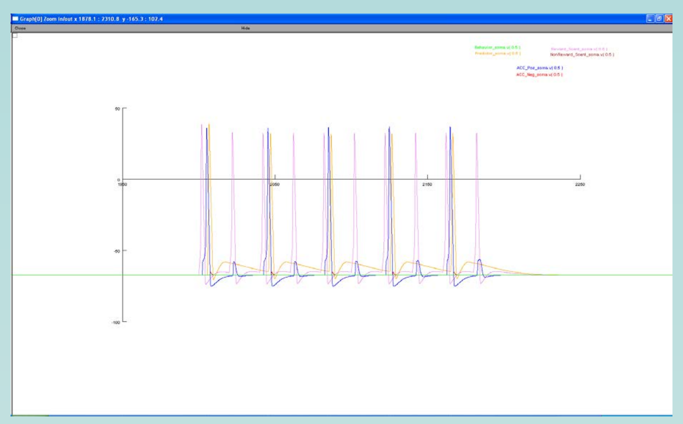
Action Potential Delays

- A faster spike correlates with the anticipated state

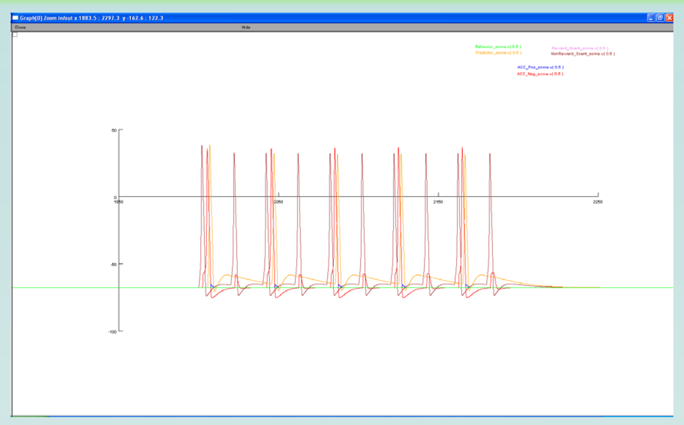


Conclusion

Our results confirmed our hypothesis:

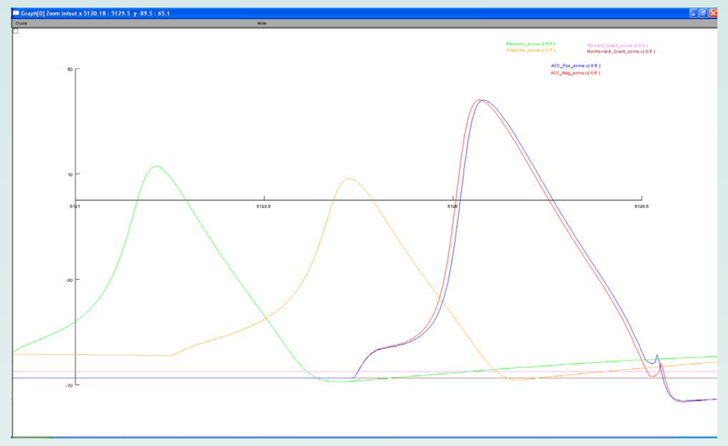


- ACC(+)1 fired during the presence of a reward stimulus



- ACC(-)1 fired during the presence of a no-reward stimulus

- Anticipation was observed in action potential amplitude and timing



  - The ACC neuron with the stronger amplitude and faster spikes represented an association with an anticipated event

Acknowledgements

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References

Noonan, M.P., Mars, R.B. & Rushworth, M.F.S. (2011). Distinct Roles of Three Frontal Cortical Reward-Guided Behavior. *The Journal of Neuroscience.* 31(40). 14399-14412.