Spiking Neurons to Model PTSD Outcomes

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*Abstract*—Current technology has only recently shown the connections between the emotional regions (amygdala) and its connection to the motor cortex. Nengo is used to gain insight into what is happening in the synapses behind the scenes that causes numbing in PTSD patients, and the synaptic connections, which explain learned helplessness. By using neurons to simulate a certain behavioral outcome in the brain, modeling using neurons in Nengo has the potential to give us new insights.

Keywords—PTSD, motor cortex, synapses, nengo

# Introduction

Nengo is an open source python library that allows the use of spiking neural networks, most commonly used to model data or to create models representing different regions of the brain. Its main benefit when compared to other techniques is power efficiency.

Most PTSD studies use Functional Magnetic Resonance Imaging (fMRI) techniques to observe patients, which tell us which regions of the brain are most active by comparing blood oxygenation levels. In one study, the dissociative response is one that shows a decreased activation in fight or flight reactions happening in PTSD patients with repeated exposure to traumatic events. (Boyer et al., 2022). As the number of events increased, the regions of their brain producing a fight or flight response became numb.

By using spiking neural networks in nengo, we can recreate these responses while gaining more insight into what is happening in the synaptic connections to create this numbing effect.

# Methods

## Checkpoint One

In the first checkpoint, I was able to simulate a “hyperactive” and “dissociative” response in response to a traumatic event. I sent a constant signal through, meant to model a traumatic event. To represent trauma responses, I implemented a learning rule in nengo, that minimized error between two functions representing a hyperactive and normal response.

## Checkpoint Two

In the second checkpoint, I changed my “traumatic event” input value to a pulse, in order to model the dissociation that comes with repeated trauma. I created a third nengo ensemble meant to represent the desired outcome. This time, the response “deadened” due to the connection between the input and the desired node using a function that multiplied the input by .75. This method allowed me to simulate learned helplessness within a single pulse rather than a constant input that can only represent one event. With the same learning rule minimizing error, the new “desired outcome” ensemble learned to become 75 percent of the original traumatic event input.

## Checkpoint Three

In the third checkpoint, I inputted a piecewise function to represent multiple traumatic event input pulses. By implementing an array that keeps a history of pulses, I was able to keep track of changes, first checking if the changes were large enough, and then identifying it as a pulse increment. Using those pulse increments, I was able to create a model that showed gradual response to inputs, showing the response decreasing over time, the synaptic weights decreasing to zero over time. In this checkpoint, the function changed to (.75) raised to the number of pulses.

# Results

1. Desired plots incrementing based on the exponent function.s
2. Combined plots with applied learning fule applied in nengo.
3. Decoder weights showing growth over time, as response learns to becomes the desired output function.
4. Error showing increases with each pulse, then flatlining to zero with enough time.

# Discussion

My project originally started with trying to use neurons to recreate FMRI, but after doing more research, I found that many deep neural networks have been used to process both FMRI and EEG. Applying spiking neural networks is a less common method, and offers more information about the behavior of the neurons themselves, and what in the brain’s synapses result could cause a deadened response. FMRI technology measures oxygen levels, which are not as accurate to detect specific regions, and EEG technology measures electrical impulses but not differing levels of connection between synapses.

If I had more time I would try to measure connections more accurately, and model the full path between each region of the brain relating to emotion to try to reach the same outcomes in nengo that model different behaviors. Minimizing the error function would be another way to improve the output, to prevent over shooting at the beginning and end of each pulse. Knowing the connections between regions can help find new paths to healing that involve re-training the synapses in regions of the brain other than the amygdala to address trauma, and restore chemical levels back to normal.

# Conclusion

The purpose state of my project is to model the changes in synaptic weights that occur when PTSD patients become numb to their surroundings due to repeated events or repeated experiences. In the future, I would like to develop this project to show connections not only in fight or flight responses within the amygdala, but the numbing effects on other regions of the brain based on what researchers currently know about brain connectivity and trauma’s tendency to negatively affect other brain regions. This concept comes from the book the body keeps the score, and spiking neural networks would be a good way for us to learn more details about the synapses, how they numb themselves, and potential paths towards healing for trauma patients.

##### References

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