3-Dimensional Agent-based Model of Neural Activity in the Central Nucleus of the Amygdala During Pain

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The central nucleus of the amygdala (CeA) is a region of the brain important in pain processing. Neurons within the CeA expressing protein kinase c-delta (PKCδ) or somatostatin (SOM) have opposing roles in pain modulation. We created a 3-dimentional agent-based model (ABM) of these neuron populations and their connectivity in the CeA to predict system-level measures of pain. The model was programmed in Netlogo 3D, specialized software for designing and visualizing 3-D ABMs, and laboratory data was used to estimate model parameters. During the model's initialization, an ellipsoid is created to represent the CeA. Within the ellipsoid, 5000 agents representing individual neurons are created with cell-type specific properties and behaviors and a network of directed links between the neurons is established. During each model time step, neurons accrue damage based on the intensity of an external stimulus, and the firing rates of all neurons are updated. Inhibitory signals are sent between neurons via the network. If a neuron's incoming signals exceed a threshold, the neuron is silenced. At the end of each model time step, a system-level measure of pain is calculated as the difference in the cumulative firing rates of PKCδ and SOM neurons. Results demonstrate the ABM's ability to output both spontaneous and evoked pain in response to noxious stimuli. We continue to refine and adapt the ABM as new laboratory data emerges. Currently, we are enhancing the ABM to include a spatial domain that accurately reflects the topology of the CeA and its subregions.