Investigating temporal evolution of motion direction judgments within a biophysically realistic network

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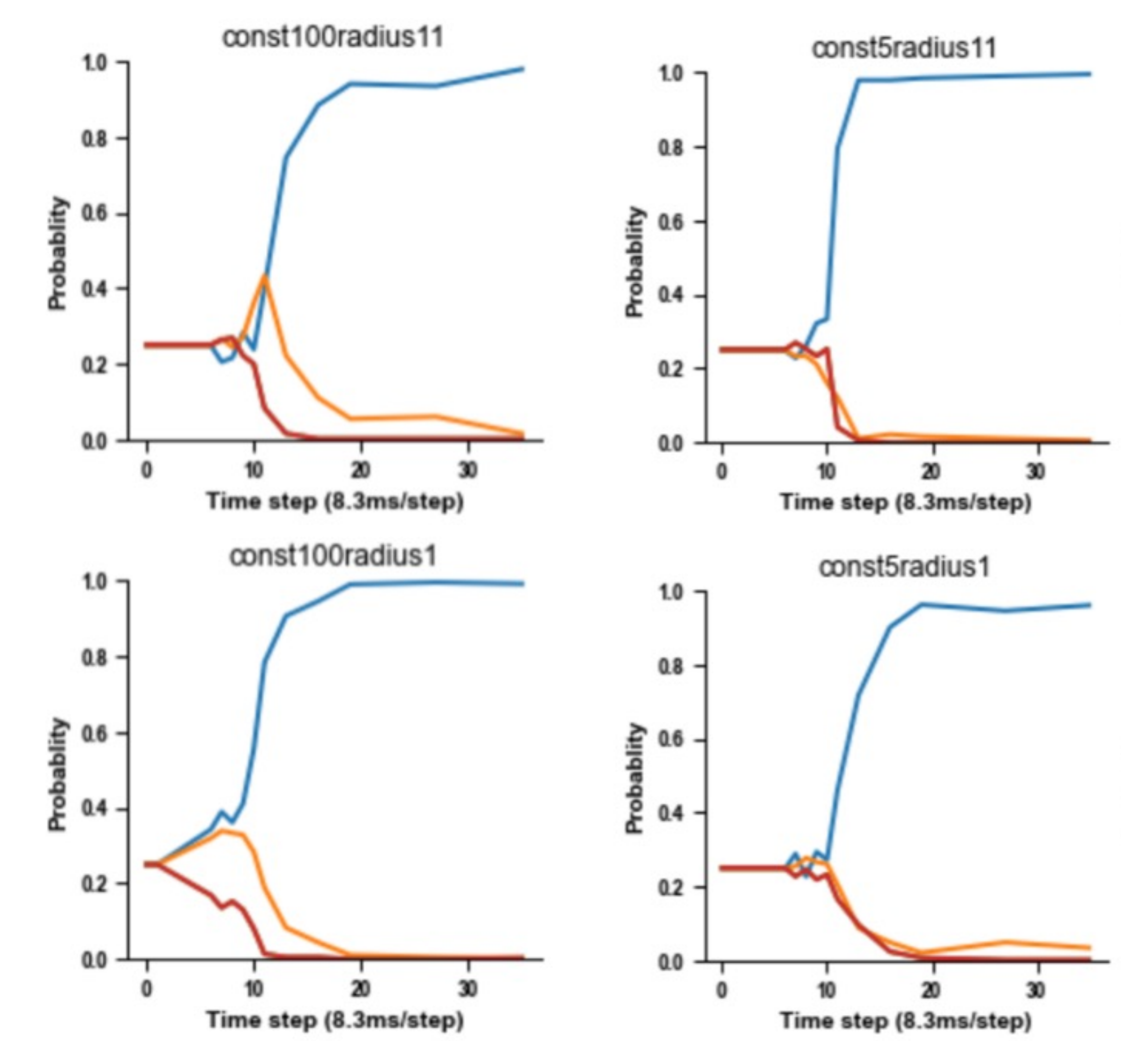
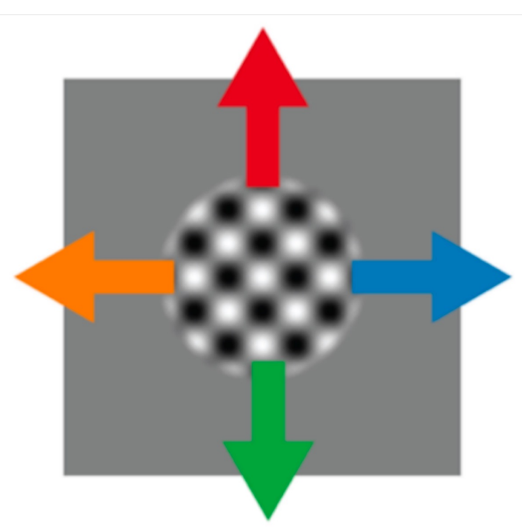
Introduction





Behavioral Data

There is a novel finding that the visual system can extract motion axis orientation before detecting motion direction. To estimate the temporal evolution of motion direction judgments, We asked participants to adjust an on-screen arrow to indicate perceived direction of moving stimuli varying in duration (rigid texture motion; randomly chosen direction; 99% contrast, 11° radius, 5°/s speed; stimuli presented at 360Hz). As expected, participants' responses were completely random for very brief stimulus motions (5ms) and distributed around the actual motion direction for long durations (>90ms). Interestingly, for intermediate durations (30-60ms), participants' responses exhibited a clear bimodal distribution with equal peaks in the actual motion direction and in the opposite direction. These results indicate that participants extract motion axis information before having a sense of the actual motion direction.

Reduced Spiking Neural Network (RSNN)

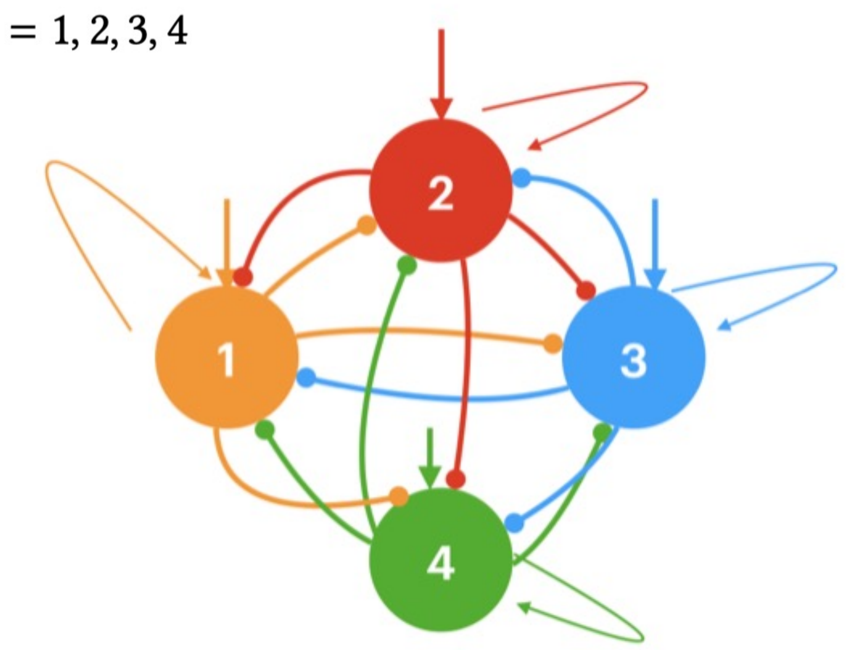
$$r_i = F(I_i) = \frac{aI_i - b}{1 - exp(-d(aI_i - b))},\quad i = 1,2,3,4$$

$$\frac{dS_1}{dt} = F(I_1)\gamma(1 - S_1) - S_1/\tau_s$$

$$\frac{dS_2}{dt} = F(I_2)\gamma(1 - S_2) - S_2/\tau_s$$

$$\frac{dS_3}{dt} = F(I_3)\gamma(1 - S_3) - S_3/\tau_s$$

$$\frac{dS_4}{dt} = F(I_4)\gamma(1 - S_4) - S_4/\tau_s$$



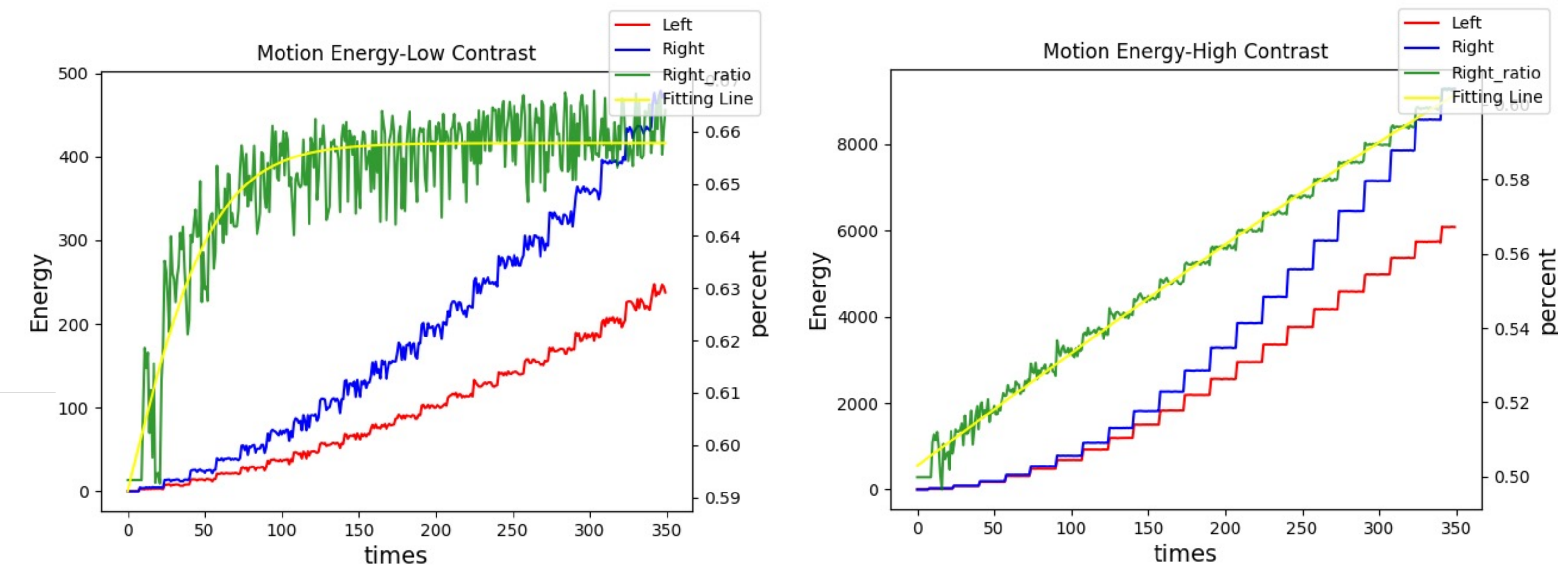
$$I_1 = J_E S_1 + J_{Iothg} S_2 + J_{Iopst} S_3 + J_{Iothg} S_4 + I_b + J_{ext}\mu_1$$

$$I_2 = J_E S_2 + J_{Iothg} S_1 + J_{Iopst} S_4 + J_{Iothg} S_3 + I_b + J_{ext}\mu_2$$

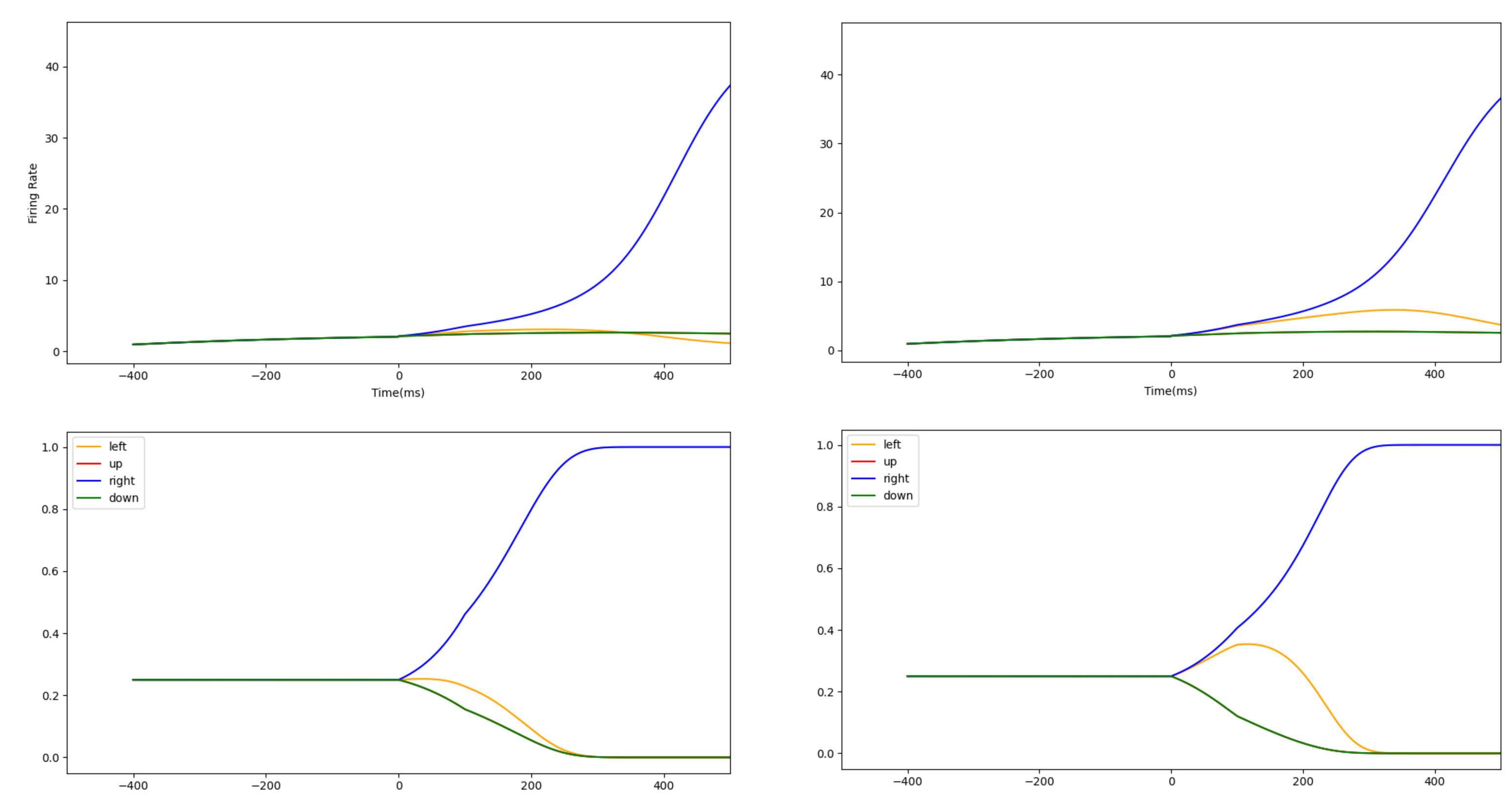
$$I_3 = J_E S_3 + J_{Iothg} S_2 + J_{Iopst} S_1 + J_{Iothg} S_4 + I_b + J_{ext}\mu_3$$

$$I_4 = J_E S_3 + J_{Iothg} S_1 + J_{Iopst} S_2 + J_{Iothg} S_3 + I_b + J_{ext}\mu_4$$

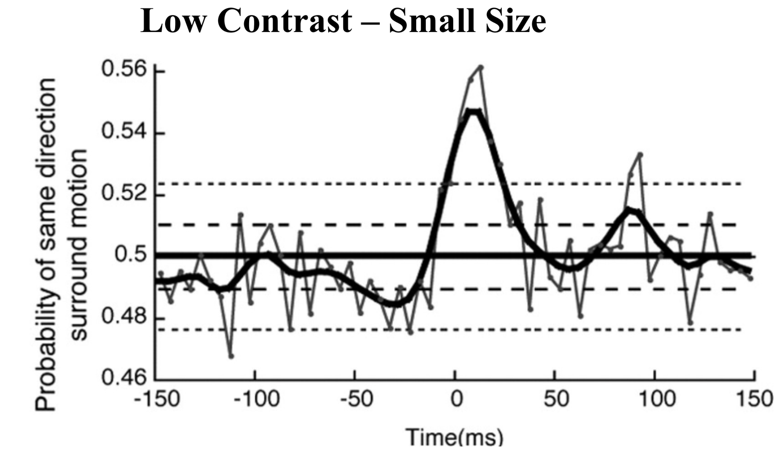
Xiaojing-Wang [13] proposed a biophysically realistic cortical network model for a binary visual discrimination experiment. For a binary visual decision-making task, the mean activity of a (homogeneous) population (left/right) can be represented by a single unit. Based on the well-developed simplified two-variable version of a biophysically realistic cortical network model of decision making [14], We extended it to a four-variable version.

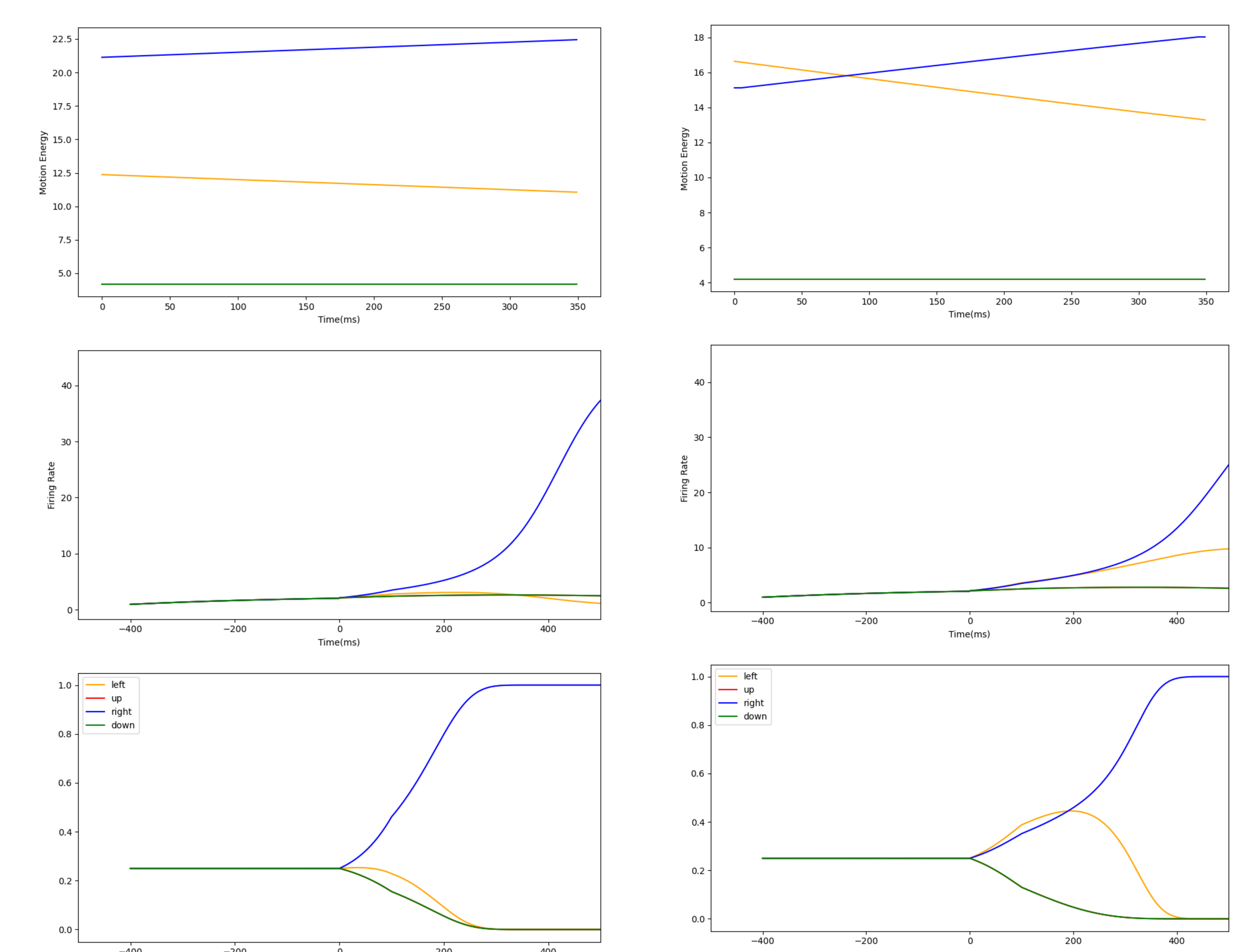


The input to the RSNN is the motion energy based on the spatiotemporal energy models [2]. It's a classical method in capturing the perception of motion, based on the outputs of quadrature pairs of filters. The first step is to compute the Fourier Transform of the stimulus, then numerically fitting the distribution of the frequencies across the time.



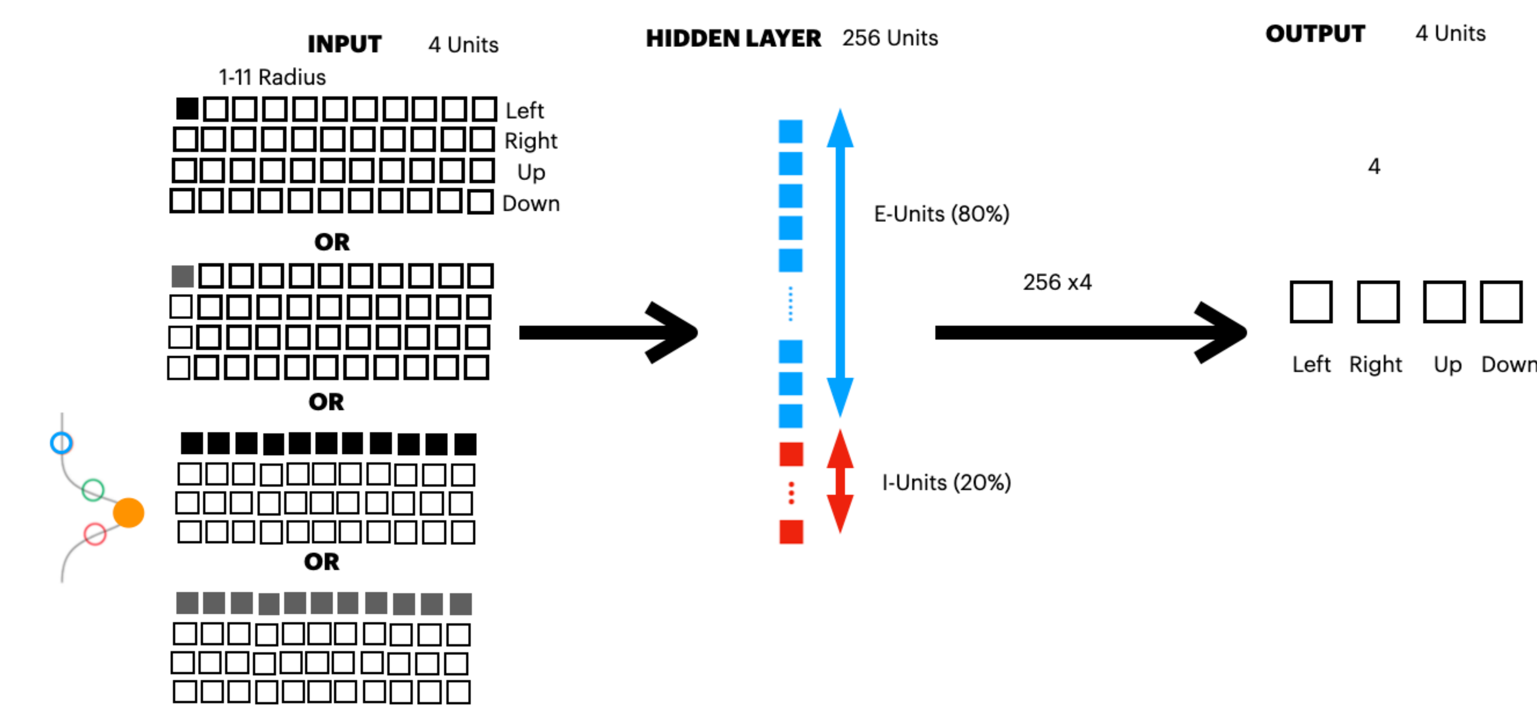
Low Contrast – Small Size High Contrast –Small Size

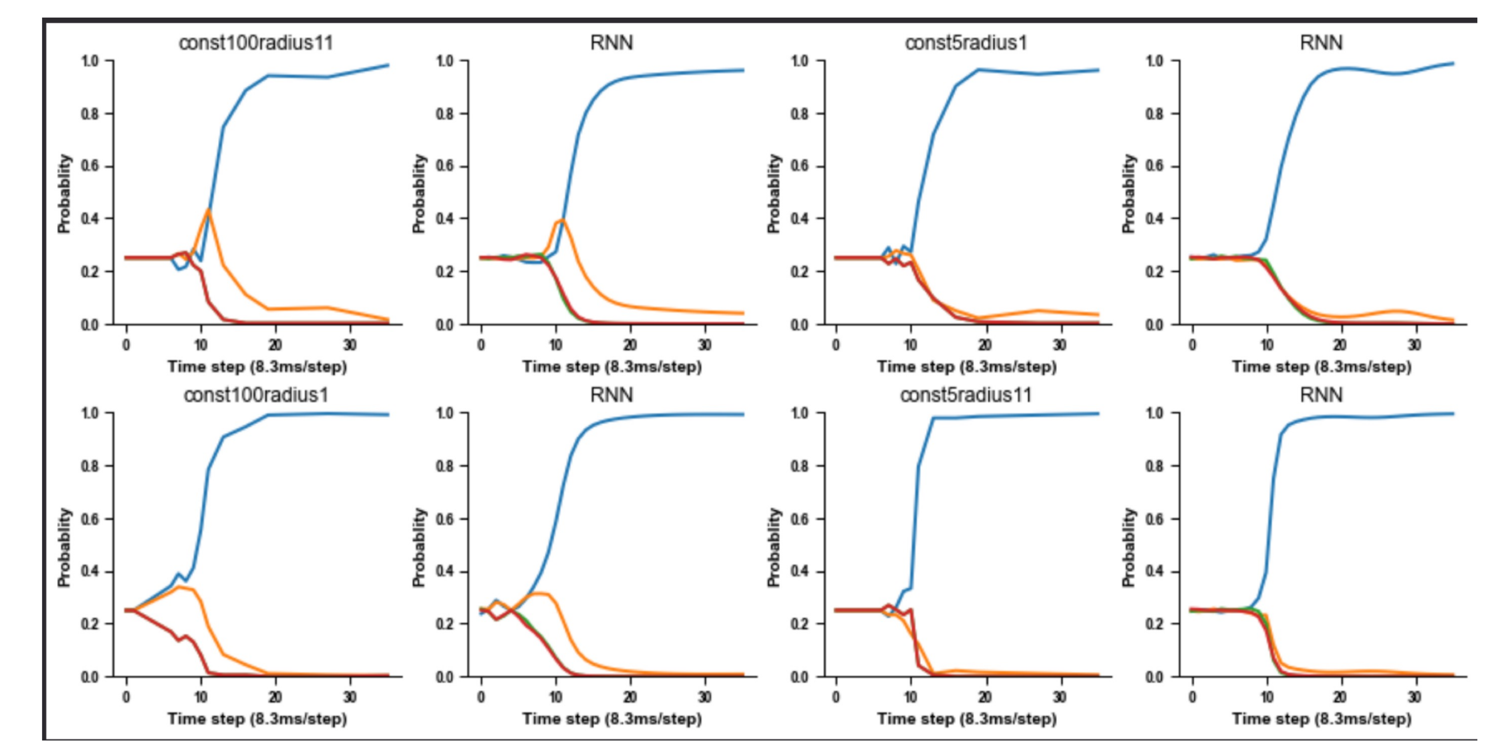


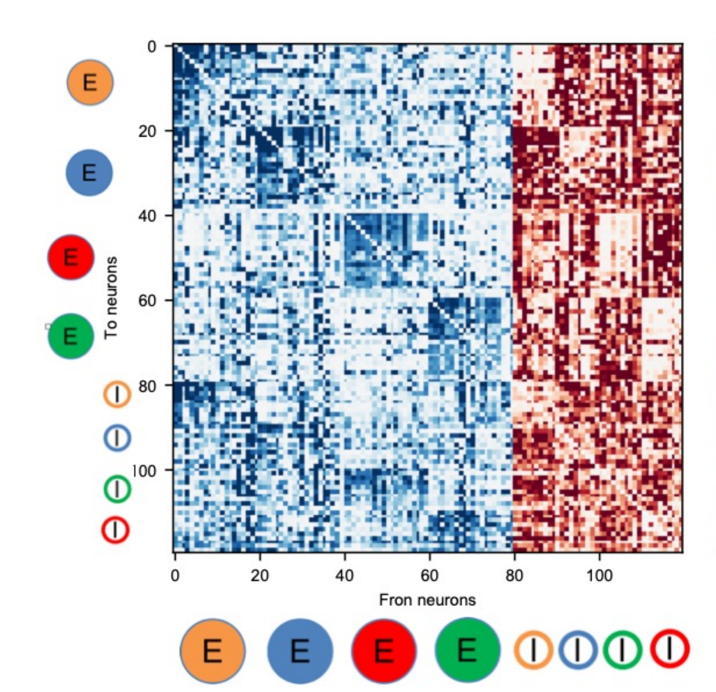


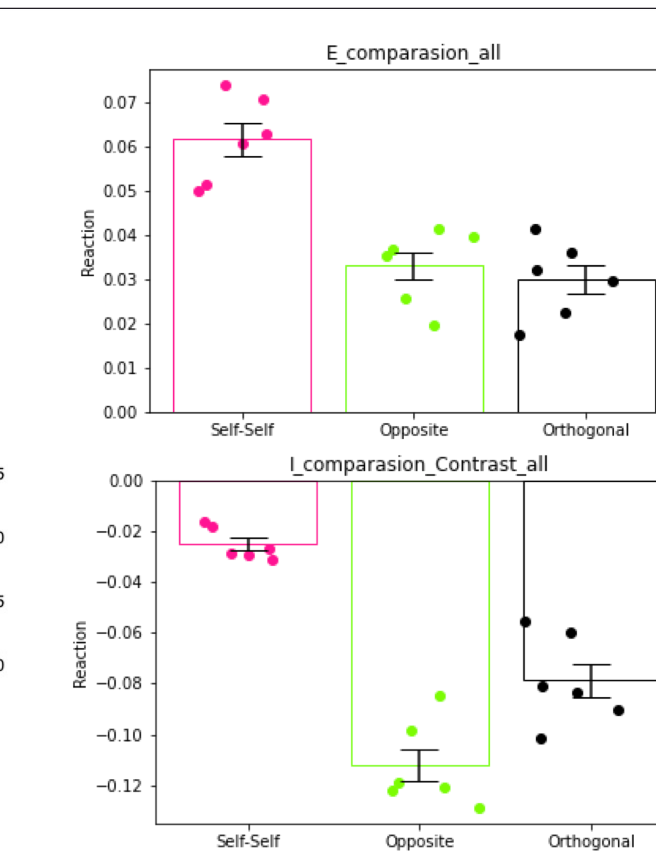
Low Contrast –Large Size High Contrast –Large Size

Excitatory-Inhibitory Recurrent Neural Network









References