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Nonlinear diffusion models of detection

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Behavioral and neuronal responses in simple detection tasks vary across repetitions under the same stimulus conditions. The probabilistic nature of both types of response is specially manifest when the intensity of the stimulus is close to the detection threshold. A recent study analyzed the neuronal responses in several cortical areas during a vibrotactile detection task [1], in which trained monkeys have to report the presence or absence of a mechanical vibration applied to one fingertip. Responses in medial premotor cortices (MPC) were found to be strongly correlated with the monkey's perceptual report, and only weakly correlated with the stimulus intensity, showing an all-or-none response after the perceptual decision has been made, with a latency determined by the stimulus strength. A recent modeling study has proposed attractor networks as a plausible framework to describe the observed properties of perceptual decision [2]. In this attractor-based description, the probabilistic activation of neurons involved in the perceptual event arises as a noise-induced transition between attractor states. Two models using biologically realistic spiking neural networks were introduced and compared in [2]. In one model, the perceptual report is encoded by the firing rates of two neural populations that compete for higher activity and are associated with the two possible behavioral outcomes. In the other model, the negative perceptual response is not explicitly encoded by the activity of a neural population, but is instead represented by the lack of activation of the neural population encoding the positive response. The main difference between the two is in their bifurcation structure: the system undergoes a pitchfork bifurcation in the first case [3] and a saddle-node in the second. Here we formally reduce both models to the corresponding one-dimensional nonlinear diffusion equations using center manifold reduction [3]. This reduction allows us to regard the detection problem as a noise-driven motion along an energy landscape whose shape is determined by the parameters of the model. With this description we can calculate, for each model, the relationship between the predicted behavioral outcomes and the parameters. We apply this framework to different model systems, such as firing rate mean-field and a spiking cell-based network, and investigate whether such broad classes of models can account for most of the salient properties observed in psychophysical and electrophysiological experiments about detection.

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