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Trading speed and accuracy by coding time: a coupled-circuit cortical model

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Our actions take place in space and time, but despite the role of time in decision theory and the growing acknowledgement that the encoding of time is as crucial as the encoding of space, few studies have considered the interactions between spatial and temporal codes in perceptual decisions. The speed-accuracy trade-off (SAT) provides a window into spatiotemporal interactions. Our working hypothesis is that temporal coding controls the SAT by gain modulation (Standage et al, Front Comput Neurosci, 2011). Here, we propose that local cortical circuits are inherently suited to coding space and time for decisions, supporting a framework of distributing temporal processing. We couple two generic local-circuit models, each consisting of pyramidal cells and inhibitory interneurons, connected by AMPA, NMDA and GABA synapses. One circuit codes time by ramping activity, seen in cortex during tasks with a timing requirement. The other makes decisions in a simulated perceptual task. The networks are identical, except the timing network is modulated by mesocortical dopamine, consistent with pharmacological studies indicating a role for dopamine in interval timing. A simple learning rule is sufficient for the timing network to quickly learn to produce new interval estimates, which show signature characteristics of estimates by experimental subjects. To trade speed and accuracy, the network simply learns longer or shorter intervals, driving the rate of decisions downstream by gain modulation. In terms of cortical function, these results should be expected of a generally uniform structure that evolved to provide a model for action in a spatiotemporal world.