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The role of temporal precision in the neural code and its relationship to the time scales of natural stimuli

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The timing of action potentials relative to sensory stimuli can be precise down to the level of milliseconds in many sensory systems, even where this observed precision is much higher than that of the sensory stimulus being presented. Observations of such temporal precision are the root of a far ranging debate over the basis of the neural code and, specifically, what time scales are important for understanding cortical computation. We address this question by studying the inputs to the visual cortex, namely neurons in the lateral geniculate nucleus (LGN) of the anesthetized cat, which exhibit a high degree of temporal precision but are typically driven by natural visual stimuli with correlation times >30 ms. Extracellular recordings of both X- and Y-cells reveal that these neurons exhibit a high degree of temporal precision that depends to some extent on the frequency content of the stimulus being presented, with an average PSTH correlation time of 3 ms observed in 120 Hz full-field stimulus conditions (8 ms frames), and 11 ms for naturalistic stimuli that have correlation times ~ 30 ms. Using information theoretic techniques, we show that the amount of temporal precision determines the range of stimulus frequencies that can be reconstructed from the spike train. This implies that a ratio of at least 2:1 between the time scales of visual stimuli and the precision of the neuronal response is required to accurately represent information present in the stimulus. This study thus demonstrates a functional role of fine-time-scale features of neuronal spike trains, and has implications for cortical computation that relies on inputs that convey information structured on these fine time scales.

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