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Marginally subcritical dynamics explain enhanced stimulus discriminability under attention

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Recent experimental and theoretical work established the hypothesis that cortical neurons operate close to critical states describing a phase transition from chaotic to ordered dynamics [1-2]. Such states are suggested to optimize neuronal information processing [3-4]. However, although critical dynamics have been demonstrated in recordings of spontaneously active cortical neurons [5], little is known about how these dynamics are affected by task-dependent changes in neuronal activity when the cortex is engaged in stimulus processing. We explore this question in the context of visual information processing modulated by selective attention: It has been shown that local field potentials (LFPs) in macaque area V4 exhibit an increase in gamma-band synchrony and a simultaneous enhancement of object representation with attention [6]. We reproduce these results using a model of integrate-and-fire neurons where attention increases synchrony by enhancing efficacy of recurrent interactions. In dependence on excitatory and inhibitory coupling strengths, we investigate the role of synchrony in enhancing stimulus processing and information transmission using information theoretical measures. We identify regions in which the diversity of activation patterns in response to different stimuli is maximized. Additionally, we compute information entropy and analyze the separability of activation patterns for different stimuli in the space of all possible activation patterns. We find that the maximum network repertoire as well as entropy maxima are associated with the emergence of synchrony near the critical points. Strikingly, only a narrow region in phase space at the transition from sub- to supercritical dynamics supports the experimentally observed discriminability increase. We therefore suggest that cortical networks operate at such near-critical states, allowing minimal attentional modulations of network excitability to substantially augment stimulus representation.

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