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ON THE PHASE RELATION BETWEEN EXCITATORY AND INHIBITORY POPULATIONS DURING HIPPOCAMPAL THETA RHYTHM. M. Tsodyks*, W.E. Skaggs, T.J. Sejnowski and B.L McNaughton. Computational Neurobiology Lab, Howard Hughes Medical Institute, The Salk Institute, La Jolla CA 92037 and ARL Division of Neural Systems, Memory and Aging, University of Arizona, Tucson AZ 85724.

We examine the dynamical behavior of a neural network consisting of two groups of cells, one whose members are excitatory to all other cells and the other inhibitory, with external oscillatory inhibitory input to the inhibitory population such as is known to occur in the septal GABAergic input to hippocampal interneurons (Freund and Antal, 1988). Using simulations and phase plane analysis, we find that over a substantial range of parameters, the behavior of the network is apparently paradoxical, in that increasing the direct external *inhibitory* input to the inhibitory cells leads them (as well as the excitatory cells) to synchronously *increase* their activity, and thus to oscillate out of phase with the external drive. The range of parameters over which this occurs corresponds closely to the range in which the excitatory network is unstable when all inhibition is removed. In the opposite regime, the inhibitory population oscillates in phase with the external drive, and out of phase with the excitatory population.

For a network operating in the vicinity of the transition between these two regimes, the inhibitory population exhibits intermediate phase shifts relative to the excitatory one. This phenomenon may be important for understanding the behavior of inhibitory interneurons ("theta cells") during the hippocampal theta rhythm, where unit recordings have revealed all three possible situations. The model may also be relevant to understanding the effects of neuromodulation in several brain regions, including the neocortex.
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