Arne D. Ekstrom & Itzhak Fried
UCLA

Single Neuron Activity in the Human Hippocampus During Virtual Navigation

Place cells of the rodent hippocampus constitute one of the most striking examples of a correlation between neuronal activity and complex behavior in mammals. These cells increase their firing rates when the animal traverses specific regions of its surroundings, providing a context-dependent map of the environment. Neuroimaging studies implicate the hippocampus and the parahippocampal region in human navigation. However, these regions also respond selectively to visual stimuli. It thus remains unclear whether rodent place coding has a homologue in humans or whether human navigation is driven by a different, visually based neural mechanism. We directly recorded from neurons in the human medial temporal and frontal lobes while patients explored and navigated a virtual town. These were patients implanted with intracranial depth electrodes in order to localize seizure focus for potential surgical resection. We found evidence for a neural code of human spatial navigation based on cells that respond to specific spatial locations and cells that respond to views of landmarks. The former are present primarily in the hippocampus, and the latter in the parahippocampal region. Cells throughout the frontal and temporal lobes responded to the subjects navigational goals and to conjunctions of place, goal and view. In addition, recording EEG from both hippocampal and neocortical sites, we found evidence for 4-8 Hz theta oscillations, which appeared related to virtual movement in all phases of the game. These findings demonstrate preservation in humans of some of the neural mechanisms identified in the rodent hippocampus but at the same time demonstrate additional properties of networks subserving human spatial navigation.