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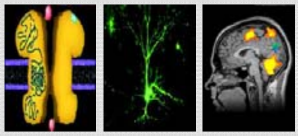

Cortical and subcortical representation of sensory and cognitive memory

April 28 - 29, 2015 Ruhr University Bochum

Tuesday April 28, morning (9:15 – 12:15)

Session 1: The temporal lobe: locus for sensory and cognitive integration?

THEODORE W. BERGER

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Engineering Memories: A Neural Prosthesis for Memory

Dr. Berger leads a multi-disciplinary collaboration that includes the University of Southern California, the City University of Hong Kong, Wake Forest University, and the University of Kentucky, and that is developing a microchip-based neural prosthesis for the hippocampus, a region of the brain responsible for long-term memory. Damage to the hippocampus is frequently associated with epilepsy, stroke, and dementia (Alzheimer's Disease), and is considered to underlie the memory deficits characteristic of these neurological conditions.

The essential goals of Dr. Berger's multi-laboratory effort include:

(1) experimental study of neuron and neural network function during memory formation - how does the hippocampus encode information?,

(2) formulation of biologically realistic models of neural system dynamics - can that encoding process be described mathematically to realize a predictive model of how the hippocampus responds to any event?,

(3) microchip implementation of neural system models - can the mathematical model be realized as a set of electronic circuits to achieve parallel processing, rapid computational speed, and miniaturization?, and

(4) creation of conformal neuron-electrode interfaces - can cytoarchitectonic-appropriate multi-electrode arrays be created to optimize bi-directional communication with the brain?

By integrating solutions to these component problems, the team is realizing a biomimetic model of hippocampal nonlinear dynamics that can perform the same function as part of the hippocampus. Through bi-directional communication with other neural tissue that normally provides the inputs and outputs to/from a damaged hippocampal area, the biomimetic model can serve as a neural prosthesis.

A proof-of-concept is presented using rats or monkeys that have been chronically implanted with stimulation/recording micro-electrodes throughout multiple regions of the CA3 and CA1 hippocampus, and that have been trained using a delayed, non-match-to-sample task (or delayed match-to-sample in the case of monkeys). After animals are well-trained, hippocampal function is blocked pharmacologically, and then in the presence of that blockade, hippocampal memory function is restored by a multi-input, multi-output model of hippocampal nonlinear dynamics that interacts bi-directionally with the in vivo hippocampus. The model is used to predict output of the CA1 hippocampus in the form of spatio-temporal patterns of neural activity representing hippocampal "memory codes"; electrical stimulation of CA1 cells is used to "drive" the output of hippocampus to the desired state (predicted memory code). Using the same procedures in implanted animals with intact, normally functioning hippocampi substantially enhances memory strength and thus, learned behavior is improved.

Most recently, the team has extended this approach to humans, with recordings from hippocampus of epilepsy patients during memory tasks, and highly successful predictive models. These results show for the first time that it is possible to create "hybrid electronic-biological" systems that mimic physiological properties of the brain, and thus, biomimetic systems that may be used as neural prostheses to restore damaged brain regions – even those regions that underlie cognitive function.