Parallel Processing and Learning: Variability and Chaos in Self-Organization of Activity in Groups of Neurons

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1. Progress on the behavioral and the molecular biological goals:

1. We have finished, as originally proposed, the software and first actual physical system for computer-controlled training procedures, with which to shape animal behavior and to perform learning-conditioning experiments.

2. We have constructed molecular biological vectors for generating muscarinic cholinergic receptor proteins pertaining specifically to all of the five known muscarinic receptors—this work follows on previous AFOSR-funded work relating to cholinergic enhancement of associative learning [14,15,11-13].

II. Progress into the implications of attractors, perturbation analysis of neurons, and the use of language theory:

3. We have developed the conceptual rationale and conducted computer experiments to show that attractor gradients provide an integrative principle that globally acts on all synapses in a network of "cooperative" neurons. The consequences of this are extensive, and much naturally falls out naturally, e.g. synaptic strengths are optimally set with one another; the size of the

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network is self-limiting; networks require trainable thresholds in their constituent neurons, along with trainable synaptic strengths, to perform even simple tasks; and both task-specific and arbitrary tasks can be performed in neural networks. We have identified the basis of variation in the action of the attractor gradients. The work began with [7,8] and its conclusions are described in the present set of publications.

4. We have identified the cellular basis for dissipative action. By analogy, it is easy to see how heat dissipates perturbations in a simple pendulum with friction. But what is that doing to the dissipative action of a central nervous system or in computer simulations of biologically realistic networks?

5. The answer to the above question in (4) has come from a series of noise and network perturbation studies of neurons and networks of neurons (The first of a series of findings is presented in [4], which will be sent to J. Neurophysiol. within the next month).

6. We have identified the basis of variation in the action of single and groups of neurons. Previous AFOSR-funded work has shown that variation is essential in adaptive function of networks that can produce many different patterns of activity [e.g., 10,11]. Here we show where the variations come from [4]. We have also obtained evidence for the mechanism by which multiple patterns emerge [2,4].

7. We have ported considerably from formal language theory and theoretical physics to describe quantitatively the trains of action potentials that are used to transmit information between neurons. Additionally, we have implemented the formalism of finite-state automata to construct machines that represent this information [3,5]. The major consequence of this work is that it provides a vast theoretical formalism with which to handle the information flow in networks. The ultimate consequence is that network function might be examined from the point of view of statistical mechanics.

8. A collaboration has been established with Dr. Seth Wolpert, Department of Electrical Engineering, University of Maine, to construct analog VLSI networks of neurons as we have described them. This work will not only allow us to perform experiments (extremely) rapidly in ways that can not be done in typical desktop computers, but it will also allow us begin to implement the findings in networks that can be rapidly trained to perform particular functions that are normally found only in behaving animals.


CITED REFERENCES OF PREVIOUS AFOSR-FUNDED WORK


