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ABSTRACT

While Amit's efforts to provide stronger theoretical and empirical support for Hebb's cell-assembly concept is admirable, we have serious reservations about the perspective presented in the target article. For Hebb, the cell-assembly was a building block; by contrast, the framework proposed here eschews the need to fit the assembly into a broader picture of its function.

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COMMENTARY

HEBB'S ACCOMPLISHMENTS MISUNDERSTOOD

Amit's work represents a significant achievement in understanding and modeling the dynamics within a Hebbian cell-assembly. Unfortunately, the target article also reveals a flawed perspective that we believe leaves Amit poorly positioned to exploit and build upon his results. This flawed perspective manifests itself in two ways. First, he fails to make contact with both empirical evidence and related models which could serve to support and inform his own efforts. (Indeed, there is a danger that the reader will be left with the impression that the cell-assembly is only now being rescued from obscurity some 45 years after Hebb proposed it.) Of greater concern, however, is the fact that these failures to make contact are not due to oversight; rather, they follow from a principled approach to cognitive modeling that involves deliberate avoidance of a broad cognitive theory. We argue this is both strategically flawed and, ironically, in direct conflict with

Hebb's perspective--Amit's position is conceptually much closer to the behaviorist position.

A BROADER SAMPLING OF EMPIRICAL EVIDENCE IS CALLED FOR

The research by Miyashita et al. provides exciting evidence for cell-assembly structures in the brain. However, in reading Amit's article, one may get the impression it is practically the only evidence. On the contrary, the research adds to a substantial existing body of empirical results on the topic. Direct evidence for maintained neural activity goes back to at least the 1950's (Burns 1951). Freeman has long studied EEG activity in the olfactory systems of rabbits and has developed an attractor model based on the results (Freeman 1975). Evidence for reverberatory activity similar to Miyashita's can be found in several lines of work (e.g., Goldman-Rakic 1990; Miller et al. 1993). For example, Goldman-Rakic has studied working memory in prefrontal cortex of monkeys and found neurons that maintained their activity for several seconds during the delay period (but not the stimulus presentation) of a delayed-response visual task. More recently, Laurent and Davidowitz (1994) reported detailed evidence for assembly-based representations of odor information in the olfactory system of locusts. They proposed that "odor quality is encoded not only by an assembly of synchronously oscillating neurons but by a particular succession of different, but overlapping, oscillating assemblies" (p. 1874).

A BROADER SAMPLING OF THEORETICAL ISSUES IS CALLED FOR

Amit is surely correct that Hebb's cell-assembly construct has received less attention than his learning postulate. As Amit notes, the most widely studied models of the past decade have been feed-forward systems--networks which are incompatible with cell-assembly theory because they are fundamentally incapable of supporting reverberation. He is not the first to note their limitations; indeed, feed-forward connectionist models have been accused of constituting a behaviorist revival (Lachter and Bever 1988; Pinker and Prince 1988; also see Kaplan et al. 1990). Nevertheless, the importance of the cell-assembly concept and of Hebb's "processing cut," as Amit calls it, has not been lost on researchers. There are in fact two classes of connectionist models compatible with the cell-assembly concept, and a large number of examples in each class. The first class includes those such as Hopfield's and Amit's that cast internal representations as attractors; representative examples include work by Anderson et al. (1977), Freeman (1975), Kanerva (1984), and Hinton and Sejnowski (1986). The second class is closer to Hebb's original conception: cell-assemblies as distinct subpopulations of neurons. These cell-assembly analogues have been variously termed "classification couples" (Edelman 1987), "recognition codes" (Grossberg 1987), "object representations" (Kaplan and Kaplan 1982), and "cell-assemblies" (Braitenberg 1984; Palm 1982).

Amit's attractor neural network, of which we see only a glimpse in the target article, is an important advance over many existing models in its coverage of biologically relevant details and the depth of its theoretical analysis. But in the context of a proposal for understanding cognitive phenomena, it must be kept in mind that the model's scope is quite limited. If one is going to propose that such network "modules" are a fundamental component of cognitive function, one must be prepared to explain something about how they work together to give rise to more complex phenomena--an issue that has been addressed in other models (e.g., Edelman 1987; Grossberg 1987; Kaplan et al. 1990) and indeed in Hebb's own theory.

CELL-ASSEMBLIES AND COGNITIVE THEORY

We believe the preceding issues are symptoms of a deeper problem. In his conclusion, Amit suggests that although cell-assemblies may "even suggest a substrate for psychology itself," constructing such a theoretical framework is a temptation we should resist, lest we get too far ahead of ourselves. He concludes:

> . . . [T]he lessons learned from these experiments include the one which advises restraint. . . . [O]ur imagination concerning brain computation is still too much constrained by formal mathematics, by computer languages, and by artificial intelligence. . . .
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> It is most likely that attending for a while longer to the details of the contact between modeling and experiment would keep options open which a premature harvest of speculation would close. [Sec. 9, p. 22]

But Hebb's Organization of Behavior must rank as one of the great "premature harvests of speculation" of our time. Nearly fifty years later, Hebb's speculations continue to influence the course of experimental and theoretical brain research, as the present enterprise, for example, plainly demonstrates. In contrast, the circumscribed, bottom-up approach and avoidance of cognitive theory that Amit argues for is actually very similar to the position taken by the behaviorists. It is interesting to note just how many of the constraints of the collective imagination Hebb was able to transcend; in the late 1940's, psychology was dominated by behaviorism and neuroscientists could offer direct evidence neither for synaptic learning nor reverberation. Perhaps even more important than his particular theoretical contributions is the example Hebb set for how to conduct a dialogue between cognitive theory and experimental neuroscience, and this Amit seems to have missed entirely.

This principled avoidance of a larger theoretical framework is not a purely philosophical problem--it has practical implications for precisely the kind of research program that Amit favors. In particular, if reverberation is to form the basis of a cognitive theory, the cell-assembly must serve as a building block in a larger, more complex system--a system which will have its own emergent dynamics that will influence the individual assemblies. If one lacks a notion of the kind of environment in which cell-assemblies function, one is unlikely to be able to explain fully their operation or explore their potential. For this reason, we fear that Amit's results--technically impressive as they are--will not easily prove to be extendable.

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