

Conceptual Coordination: How the Mind Orders Experience in Time

by William J. Clancey

Mahwah, NJ: Lawrence Erlbaum Associates, 1999. 395 pp. ISBN 0-8058-3143-6. \$89.95

Review by Melanie Mitchell

This book is about the nature of human memory, and how it differs from processes in computers. Clancey's foil is the traditional "computational" approach to cognitive science in which memory consists of the storage and retrieval of symbolic variables. He challenges the "taken-for-granted" assumptions that knowledge actually is stored in some location in long-term memory even when it is not being used, that it can be retrieved, held, and analyzed in a kind of buffer-like working memory, and that multiple pieces of knowledge can simultaneously be held active in this way. These processes are central to computer memory, and he argues, have been taken for granted in cognitive models as well.

In Clancey's view, memory consists not of the storage and retrieval of symbols, but of a dynamical process of activation of physically connected neural structures. New memories or concepts are embodied as physical relations between structures in the brain that include not only an encoding of some external contents but, very centrally, the perceptual and motor activities making up "what I am doing now". *Remembering* consists of an approximate re-activation of these structures, in place and in sequence, with the possibility of substitutions, reconstructions, and new interpretations. In this view, a few basic processes at the neural level can explain many different aspects of memory: declarative, episodic, motor, perceptual, etc.

Temporal sequential associations are the essence of Clancey's theory of memory, and are, he believes, what underlies much of cognition. Inferences rules, for example, such as "X implies Y", are stored not in a symbolic fashion ("IF X THEN Y", encoded somehow in neural tissue) but as a temporal relation between two neural structures: when the structure encoding X is active, it activates the structure encoding Y. Thus, what memory does is to coordinate concepts and behavior in time. This is achieved at several levels: sequences of primitive "categorizations", sequences of sequences (what Clancey calls "conceptualizations), and so on.

These ideas are, of course, not very new in cognitive science. In basic form they go back as far as William James, and in details closely mirror the work of Donald Hebb and Frederick Bartlett, and that of the Gestalt psychologists. Clancey explicitly credits these various people for much of the impetus for this book, saying that he wants to better link their work with the understanding of actual physical processes in the brain. In modern times similar ideas are behind much of the work in connectionist modeling and more recent speculations about the role of dynamical systems theory in explaining cognition. What is new in this book is a detailed exposition and extension of these basic ideas, revealing the deep links between perceptual-motor skills and higher-level cognition, a detailed re-examination and recasting of well-known cognitive phenomena and models into this "conceptual coordination" framework, yielding some interesting novel explanations, and a preliminary link to some recent research in neuroscience.

Clancey's book explores the constraints imposed by his view of the physical architecture of memory. These constraints forbid both copying and the simultaneous multiple use of a single categorization (or concept). They also constrain the ways in which substitutions can be made or concepts can be adapted in various contexts. This leads to discussions of how errors or "slips" take place in action and language, reformulating some of Donald Norman's work in this area, and of how analogies are created, including a review of the most prominent models of analogy-making and how they fit into Clancey's framework. He also uses the constraints implied by his theory to explain why certain grammatical constructions are more difficult to parse than others. Clancey's work on grammatical constraints is the strongest part of the book, showing how his proposed architecture of the reactivation, substitution, and composition of sequences of perceptual categories, and the constraints entailed by such an architecture (such as the inability to arbitrarily copy symbols), give a very convincing and parsimonious explanation for differences in understanding center-embedded structures versus right-branching structures.

Clancey also shows how Jeffrey Elman's model of sequence learning and Gerald Edelman's model of categorization fit into his broader theory. He also analyzes, with respect to the conceptual coordination framework, some earlier work in symbolic artificial intelligence, including Neomycin, NL-Soar, and the memory models of Feigenbaum, Newell and Simon, and Schank.

Clancey summarizes his analyses in terms of "activation trace diagrams", which are abstract renderings of his assumptions about how different neural structures encoding categories are physically related and of the temporal flow of activity through these structures. I found these diagrams most useful in the context of explaining grammatical processing; in many of the other cases they did not add much information to the discussion in the text. Beyond making the point that structures representing categories are physically and temporally related in the brain, these diagrams (like the explanations in the text) do not give insight as to any actual neural mechanisms or hypothesize how such categories and their connections might be implemented at the neural level. This is acknowledged by Clancey—he points out that they are meant to "reveal patterns in neural processes", not "mechanisms". However, these diagrams have a curiously symbolic feeling to them, with categories being represented as linguistic descriptions, which is a bit strange for a framework that claims to reject the traditional symbolic approach to cognitive science. Although he intends them only as shorthand for still-unknown neural processes they give the impression of a less-radical break with the old approaches than perhaps Clancey intended.

The major strengths of this book are its excellent reviews of several different cognitive phenomena and models, and its presentation of a relatively simple unifying framework in which these various phenomena and models can be cast. A major weakness is the abstract, high level of description of the framework; in spite of the many references to "neural activation", "neural structures", and the like, Clancey does not really discuss how his ideas might be implemented at the level of neurons, beyond a short description of the roles the cerebellum and cerebral cortex might play in sequential processing. While Clancey's theory is admittedly "architectural", he does not make it very clear how neural modelers should proceed to verify it, or what kind of structures experimentalists should look for. One useful

insight he does offer is that the learning of behavioral sequences at all levels of thought is closely related to sensorimotor coordination.

Similarly, while it is Clancey's explicit goal to "invent a new 'computational' architecture (i.e., an artificial mechanism)" for conceptual coordination, this is not something he does in this book; there are no computer simulations of his own testing out the workability of any of these ideas, or guidance for would-be modelers.

Another weakness is the absence of discussion of many other people's ideas about sequential memory and conceptual coordination in time. As just one example, the work of Pentti Kanerva and of Teuvo Kohonen on neural modeling of associative memory and temporal sequential thought, while seemingly closely related to Clancey's concerns, is not mentioned. Neither is much of the work on dynamical systems approaches to cognitive modeling, also importantly related to Clancey's approach.

In spite of these weaknesses, this book is worth reading for its new formulations of classic models and explanations in cognitive science, and for its nascent but important attempts to formulate a new approach and vocabulary at describing dynamical processes in memory. Clancey himself describes his analysis as an "imaginative exploration", which is a necessary step toward more rigorous and neurally detailed understandings of these very complex phenomena.