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Contemporary Views on the Origin of Life, Mind and Society

Edited by

FRANCISCO J. VARELA AND JEAN-PIERRE DUPUY
CREA, École Polytechnique, Paris, France

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PREFACE

The main intention of this book is to bring together contributions from biology, cognitive science, and the humanities for a joint exploration of some of the main contemporary notions dealing with the understanding of origins in life, mind and society.

The question of origin is inseparable from a web of hypotheses that both shape and explain us. Although origin invites examination, it always seems to elude our grasp. Notions have always been produced to interpret the genesis of life, mind, and the social order, and these notions have all remained unstable in the face of theoretical and empirical challenges. In any given period, the central ideas on origin have had a mutual resonance frequently overlooked by specialists engaged in their own particular fields.

As a consequence, this book should be of interest to a wide audience. In particular, for all those engaged in the social sciences and the philosophy of science, it is unique document, since bridges to the natural sciences in a mutually illuminating way are hard to find. Whether as a primary source or as inspirational reading, we feel this book has a place in every library.

The material comes from an international meeting held in September 13—16, 1987 at Stanford University, organized by F. Varela and J.-P. Dupuy at the request of the Program of Interdisciplinary Research of Stanford University. We are grateful to René Girard, the Program Director, for making it possible with the help of the Mellon Foundation. Our thanks also to Laurence Helleu for her skillful editorial help in the preparation of this book for publication.

In preparation for the Symposium, Andrew McKenna, André Orléan, Stuart Kauffman, Thomas Bever, and Francisco Varela were asked to prepare position papers which were circulated in advance to invited discussants who presented their comments during the meeting itself. The full program and list of participants is included in an Appendix. This book contains revised and updated versions of the position papers, a selection from discussants' presentations, and special lectures given by René Girard and Umberto Eco. The exception is the section on the

Francisco J. Varela and Jean-Pierre Dupuy (eds), Understanding Origins, vii—viii.

CHRISTINE A. SKARDA

PERCEPTION, CONNECTIONISM, AND COGNITIVE SCIENCE

I. INTRODUCTION

Recent findings in neurophysiology and cognitive science point to the same conclusion: cognition can be explained without appeal to the representations and rules of earlier cognitivist explanations. Yet if this is true, we want to know what form the alternative explanation will take and what processes are responsible for cognitive phenomena like perception. In this paper I discuss three issues: (1) the correct characterization of the alternative to cognitivism; (2) the resulting view of perception based on the alternative; and (3) the implications of this alternative explanatory framework for cognitive science.

II. CONNECTIONIST OPTIONS

Varela offers two options to traditional 'cognitivism' (the view that cognition can be explained in terms of formal symbol manipulation). One of these options he terms 'emergence', the other 'enaction'. Emergent systems are equated with current connectionist approaches, while enactive systems are viewed as a non-connectionist, second option to cognitivism. I would like to reformulate this: there is an important distinction to be made here, but it is not the one Varela makes in his paper.

In a recent paper (Freeman and Skarda, 1988), Walter Freeman and I suggest that it is important to distinguish two camps of present-day connectionist models, one typified by so-called PDP systems (Hinton, 1985; Rummelhart *et al.*, 1986), the other characterized by self-organizing dynamical systems (Amari, 1983; Freeman, 1975; Grossberg, 1981; Hopfield, 1982; Kohonen, 1984). Varela conflates these two classes of connectionist models in his paper when he describes connectionist systems as *distributed systems* that are also *self-organized*.

Distributed systems are not *eo ipso* self-organizing systems. Systems that fall within the PDP class of connectionist models use *globally*

Francisco J. Varela and Jean-Pierre Dupuy (eds), Understanding Origins, 265–271.

distributed dynamics, but there is a sense in which this class of systems still uses internal representations in the production of behavior. Systems like these, that rely on feed-forward connectivity and back propagation for error correction, have their 'goals' externally imposed. As Varela points out, they require a 'teacher' or set of correct answers to be introduced by the system's operator. These answers are paradigmatic patterns with reference to which the output of the system is corrected via error correction. The teacher may not be contained in a program, but it functions in the same way as an internal representation does in conventional computers.

Some connectionist systems, however, are self-organized systems. Self-organizing dynamic systems, because of dense local feedback connections, do not require or use teachers. No matching or comparison takes place such as by correlation or completion, and no archetypal set patterns are placed by an external operator into the system as its goals. Self-organized systems do not fall prey to the criticisms Varela levels at 'connectionist' systems.

It is misleading to identify, as Varela does, connectionism with self-organizing, *emergentist* systems, and to say that *all* connectionist systems are still wedded to the representations of traditional cognitivism. Some connectionist models are self-organizing, but others are not. All connectionist systems use distributed, highly parallel processing, but that is not the same thing as being self-organizing. PDP systems are susceptible to Varela's attack on representations, self-organized systems are not. I believe that Varela's distinction between emergent and enactive systems is ultimately intended to capture the same fundamental distinction, but it is mistaken to equate emergent systems with connectionism as a whole and set all connectionist systems against the enactive approach. This dichotomy is a false one.

I believe that this point of clarification is important for two reasons. First, if Varela would draw the distinction as I have rather than as he has, his own position would be strengthened by being corroborated by an important class of connectionist models. Second, historically calls for an alternative to cognitivism have been beset by vagueness concerning what form the alternative would take. In order to adopt a nonsymbolic, nonrepresentational approach to cognition we need more than the phenomenologists of the continental tradition have produced, more than discussions of why knowledge is a matter of 'being in a world', more than Varela's claim that cognition is an "on-going interpretation which cannot be adequately captured as a set of rules and assumptions since it is a matter of action and history, an understanding picked up by imitation and by becoming a member of an understanding which is already there". As cognitive scientists we want a model of how this self-organized interaction works. Self-organizing connectionist systems are a step in the direction of defining a nonrepresentational alternative in cognitive science, and as such they are of crucial importance.

III. REDEFINING PERCEPTION

The recognition of self-organizing systems is important because it forces a redefinition of perception along the lines sketched by Varela under the term 'enaction'. Data gathered in Freeman's laboratory has led to similar conclusions and serves as a concrete example in the present context.

Both symbol-based and distributed PDP models of perception view perception as a process initiated by the causal impact of an object on the system that leads to the formation of a more or less adequate internal representative of that object and its features. Perception on this model is a reaction to something that is initiated at the receptor level, it is pick-up, detection, representation of some object or state of affairs. Varela neatly summarizes this position in his paper.

Investigation of sensory processing in the olfactory bulb leads to a very different picture of perception (Freeman and Skarda, 1985). Neural dynamics in the bulb are self-organizing. Evidence indicates that when an organism is trained to respond to a particular odor a self-organized process in the bulb produces a spatially coherent state of patterned activity that can be modelled mathematically as a limit cycle attractor. With each inhalation, after learning and in the presence of this odor, this more ordered state repeatedly emerges from the background state which itself is self-organized. A separate spatial pattern of periodic behavior forms for each odor given under reinforcement. When the reinforcement contingency is changed in respect to any one odor, or if a new odor is added to the repertoire under reinforcement, all the spatial patterns undergo small changes during the process of learning. These changes do not occur in the olfactory bulb if there is no reinforcement or if the newly learned CS is not olfactory but visual or auditory.

With respect to perception several features of the neural dynamics are worthy of note. (1) Only when the odorant is reinforced leading to a behavioral change, i.e. only when the stimulus input has some behavioral significance for the organism such that it acts on the stimulus, do odor-specific activity patterns form in the olfactory bulb. Presentation of odorants to the receptors in unmotivated subjects does not lead to any observable changes in the system. (2) Odor-specific activity patterns are dependent on the behavioral response: changing the reinforcement contingency changes the patterned activity previously recorded. (3) The self-organized, internally generated patterned activity is context dependent: introducing new reinforced ordorants to the animals' repertoire leads to changes in the patterns of all previously learned odorants.

These findings have important implications for how we view perception. First, perception does not begin with causal impact on receptors; it begins within the organism with internally generated (self-organized) neural activity that, by re-afference, lays the ground for processing of future receptor input. In the absence of such activity, receptor stimulation does not lead to any observable changes in neural dynamics in the brain. It is the brain itself that creates that conditions for perception by generating activity patterns that determine what receptor activity will count for it. Perception is interaction initiated by the organism, not reaction caused by the object at the receptor level. Thus, the story of perception cannot be told simply in terms of feed-forward causation in which the object initiates neural changes leading to an internal perceptual state. What is missing in the reflex-based model is recognition of the role played by self-organized neural processes and by dense feedback among subsystems in the brain that allow the organism to initiate interaction with its environment.

Second, the fact that odor-specific activity patterns change whenever new odors are added to the repertoire or when reinforcement contingencies (behavioral responses) are altered, indicates that perception is not internal representation of an object. The self-organized neural activity we record reflects a process of reliable interaction in a context. These patterns reflect not just the presence of an odorant, or the response, but both in interaction along with a context of other significant odorants in which this behavior is embedded.

These findings provide neurophysiological support for a nonrepresentational, cognitive alternative for cognitive science. Varela's critique of problem solving and representation, and his emphasis on what he terms 'enaction', I take to be another way of getting at a view of perception that Freeman and I have developed on the basis of olfactory processing.

IV. IMPLICATIONS FOR COGNITIVE SCIENCE

The self-organized property of brain dynamics also has important implications for cognitive science because self-organized systems require an explanatory framework alien to that used traditionally in science (Skarda, 1986). Explanations, including those in cognitive science, have been attempts to understand system properties in terms of the properties of the input to the system and of the parts that constitute the system. Yet, explanations of self-organizing phenomena can only be given in terms of qualitative forms of behavior of the system as a whole. These system properties resist analysis in terms of the properties of the parts that comprise the system or in terms of properties of the input to the system. In explaining such phenomena there is relative independence from the nature and properties of the substrate; hence microreduction, the aim of traditional explanations, does not work (Garfinkel, 1981). Cognitive science must take this into account.

The requirement for a new explanatory model to deal with brain dynamics underlying perception and behavior is further underscored by the role played by chaotic neural activity. The term 'chaos' refers to dynamic activity that appears random, but is not. Such activity exists in many forms and degrees, has precisely definable characteristics and relatively few degrees of freedom, and can be reliably simulated, generated, or reproduced if initial conditions are identical and known. Chaotic activity has been identified in more than one brain area (Babloyantz and Destexhe, 1986; Nicolas and Tsuda, 1985; Freeman and Viana Di Prisco, 1986; Garfinkel, 1983), and we have postulated that it may provide the basis for the flexibility and adaptive coping that make possible successful interaction with an unpredictable environment (Skarda and Freeman, 1987)

The observation that brains employ chaos to produce behavior is important in the present context because it is known that chaotic phenomena preclude all long-term predictions. It may seem paradoxical to make this claim about a deterministic phenomenon, but in systems that exhibit chaotic behavior small uncertainties are amplified by the nonlinear interactions of a few elements. The upshot is that behavior that was predictable in the short run become intrinsically unpredictable in the long term (Crutchfield *et al.*, 1987). As a result, physiologists cannot make strict casual inferences from the level of individual neurons to that of neural mass actions, nor from the level of receptor activity to internal dynamics. Thus chaotic, self-organized systems challenge the traditional reductionist paradigm of explanation that lies at the heart of cognitive science. Qualitative descriptions of global system dynamics replace the reductive explanations of the past. Moreover, these phenomena make long-term predictions intrinsically impossible, they cut the causal connection between past and future. Taken together, these facts imply a change in the nature of explanations in cognitive science and a new direction for future research.

CREA, Ecole Polytechnique, Paris

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