Chapter 4.4
Environmental Variability and the Emergence of Meaning:
Simulational Studies Across Imitation, Genetic Algorithms, and Neural Networks

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ABSTRACT

A crucial question for artificial cognition systems is what meaning is and how it arises. In pursuit of that question, this paper extends earlier work in which we show the emergence of simple signaling in biologically inspired models using arrays of locally interactive agents. Communities of "communicators" develop in an environment of wandering food sources and predators using any of a variety of mechanisms: imitation of successful neighbors, localized genetic algorithms and partial neural net training on successful neighbors. Here we focus on environmental variability, comparing results for environments with (a) constant resources, (b) random resources, and (c) cycles of "boom and bust." In both simple and complex models across all three mechanisms of strategy change, the emergence of communication is strongly favored by cycles of "boom and bust." These results are particularly intriguing given the importance of environmental variability in fields as diverse as psychology, ecology and cultural anthropology.

INTRODUCTION

Meaning is crucial to cognitive systems. It can be expected to be as crucial for artificial cognitive systems as it is for the ones we find occurring naturally around us, or indeed for the cognitive systems that we ourselves are. A crucial question for artificial cognition, then, is what meaning is and how it arises.

This paper is a development of earlier work in which we study the emergence of simple signaling in simulations involving communities of interacting individuals. Crucial to the model is an environment of wandering food sources and predators; our agents are "embodied" in an artificial environment and subject to its spatial and temporal contingencies. Crucial to the model is also the fact that it is not a single individual but a community of potentially interacting individuals that are embedded in such an environment. Our individuals develop coordinated behavioral strategies in which they make and respond to "sounds" in their immediate neighborhoods. Crucial to variations of the model explored here are different updating mechanisms of strategy change, all of which key to the behavior of most successful neighbors.

What our earlier work has shown, using any of various updating mechanisms in such a model, is the consistent emergence of communities of communicators using simple patterns of signaling. In an environment in which food sources and predators wander in a random walk, communities of individuals emerge that make a particular sound on successfully feeding, and respond to that same sound from neighbors by positioning themselves to feed. They make a different sound when hit by a predator, and respond to *that* sound from immediate neighbors by "hiding." Our models are biologically inspired in emphasizing strategy changes across a community of individuals embodied in a common environment. What consistently emerges are coordinated strategies of behavior that look a lot like simple signaling, and thus offer at least one clue to one kind of meaning.

What we introduce in this paper is a further characteristic of environments: variability. Our essential question is what role environmental variability—and environmental variability of what type—may play in the emergence of simple communication. Our inspiration comes from the role that environmental variability seems to play in a range of apparently disparate phenomena, from species diversity to individual learning.

In behavioral psychology, environmental variability has long been established as an important factor in operant conditioning. Intermittent schedules of reinforcement prove far more effective than constant reinforcement; variable-ratio schedules of reinforcement generally produce the highest number of responses per time period, establishing behavior most resistant to extinction (Reynolds, 1975; Honig & Staddon, 1977). "A pigeon may peck the key 50 to 100 times after reinforcement has been cut off if it previously was on a schedule of continuous reinforcement. After some types of intermittent reinforcement, the bird will peck from 4,000 to 10,000 times before responding extinguishes" (Nye, 1992, p. 31).

In ecology and evolution, rates of environmental fluctuation have been proposed as a major factor in inter-species dynamics. A number of different mechanisms have been proposed linking environmental fluctuation to increased species diversity (Hutchinson, 1961; Harris, 1986; Huston, 1979; Hubbell & Foster, 1986; Chesson & Huntly, 1989, 1997). It has recently been proposed that Pleistocene climatic fluctuations are responsible for the evolution of larger brained mammals in general and higher primates in particular, with suggested links to social learning (Potts, 1996; Opdyke, 1995; Odling-Smee, Laland, & Feldman, 2000; Boyd & Richerson, 1985, 1989, 2000).

In cultural anthropology, variable environments appear to play a major role in the transition from foraging cultures to incipient agriculture. In a comprehensive computer model for archaeological data from the Guilá Naquitz cave site, R. G. Reynolds characterizes climate in terms of wet and dry years. Wet years show a wider range of food-acquisition behaviors with more new strategies, while dry years show a concentration on competitive and efficient strategies, with more critical pressure on strategy choice. Reynolds explains the role that environmental variability may play in the emergence of agriculture:

The selective pressure placed on the group can vary unpredictably, and it is this variation that

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