Synthetic Ethology: A New Tool for Investigating Animal Cognition
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1. Goals

Synthetic ethology is based on several methodological commitments. First, it is based on the conviction that the investigation of cognition should investigate behavior and the mechanisms underlying that behavior in the agents' environment of evolutionary adaptiveness. Second, that this investigation should extend over structural scales from the neurological mechanisms underlying behavior, through individual agents, to the behavior of populations, and over time scales from neurological processes, through agents' actions, to the evolutionary time scale. Obviously, such a wide range of scales is difficult to encompass in investigations of natural systems. Third is the observation that the discovery of deep scientific laws (especially quantitative ones) requires the sort of control of variables that can be achieved only in an artificial experimental setup.

Therefore we are faced with conflicting demands. On the one hand, we need precise experimental control. On the other, ecological validity dictates that agents be studied in their environment of evolutionary adaptiveness, where are there are innumerable variables, which are not amenable to independent control. *Synthetic ethology* intends to reconcile these conflicting requirements by constructing a synthetic world in which the phenomena of interest may be investigated. Because the world is synthetic, it can be much simpler than the natural world and thereby permit more careful experimental control. However, although the world is synthetic and simple, it is nevertheless complete in that the agents exist, live, and evolve in it.

The original motivation for synthetic ethology came from one of the central problems in cognitive science: the nature of *intentionality*, the property that makes mental states *about* something. We felt that an understanding of intentionality would have to encompass both the underlying mechanisms of intentional states and the social-evolutionary structures that lead to the creation of shared meaning. Our analysis of intentionality concluded that something is *intrinsically meaningful* to an agent when it is potentially relevant to an agent or to its group in its environment of evolutionary adaptedness (MacLennan 1992). Therefore intentionality must be studied in an evolutionary context.

We began our investigation with communication, since it involves both intentionality and shared meaning. We will show in this chapter how synthetic ethology permits the investigation of signals that are inherently meaningful to the signalers, as opposed to those to which we, as observers, attribute meaning.

2. Methods

The agents that populate our synthetic worlds can be modeled in may different ways; in particular there are a variety of ways of governing their behavior, including simulated neural networks and rule-based representations. In the experiments described here, an agent's behavior was controlled by a set of stimulus-response rules (64 rules, in these experiments). These rules were determined by an agent's (simulated) genetic string, but the may be modified by a simple learning mechanism (described below).

Since our goal is to investigate the synthetic agents in their environment of evolutionary adaptedness, they must evolve. Therefore our world includes a simplified form of simulated evolution, which proceeds as follows. Periodically two agents are chosen to breed, the probability of which is proportional to their "fitness" (as described later). The genetic strings of the two parents are mixed so that each of the offspring's genes comes form one or the other of the parents. In addition, there is a small probability of a gene being mutated. The resulting genetic string is used to create the stimulus-response rules for the single offspring, which is added to the population. In order to maintain a constant population size (100, in these