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Does Probability Matching Require Complex Representations?

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Introduction

Representational approaches to animal behavior (e.g., Gallistel, 1990; Myerson and Miezin, 1980) posit that complex group behavior results from complex representations of events within the central nervous systems of individual animals. For example, ducks feeding from two food sources distribute themselves proportionately to the density of food available at each source. This phenomenon, probability matching, is typically explained by attributing representations of the density of food available at each source within the CNS of each duck.

Are such complex representations necessary to explain probability matching? Drawing on the ecological approach to perception (e.g., Gibson, 1986) and on methods used in artificial life research (e.g., Reynolds, 1987), I propose a simpler model, in which probability matching emerges when each animal follows a simple behavioral rule (go to the nearest morsel of food), and a simple constraint of the environment is assumed (larger morsels take longer to eat than smaller morsels).

Simulations

In order to compare non-representational and representational models, I implemented both in computer simulations. The rates of dispersal and the magnitude of food "morsels" at two food sources on opposite ends of a "pond" could be specified. During a simulation, when a duck made contact with a morsel of food, the duck would remain stationary until it was finished "eating." Eating time, in update cycles, was defined as the magnitude of a morsel of food; given a morsel of magnitude 5, a duck eating that morsel would remain stationary for 5 update cycles. At the beginning of a simulation, a specified number of ducks was randomly distributed throughout the pond. At each time step, or cycle, food was distributed near a source according to that source's dispersal rate. Subsequently, the locations of the ducks were updated in random order, either in accordance with the constraints of the non-representational model, or based on representations of food density at each food source. Fifty simulations were run with both models.

Results and Discussion

Most importantly, the non-representational simulation demonstrated that complex representations are not necessary to explain probability matching, as it can account for data from probability matching experiments. For example, Harper (1982) reported that real ducks matched 1:2 dispersal rate ratios within approximately 90 seconds, and 1:2 morsel magnitude ratios within approximately 300 seconds. In the non-representational simulation, differences in rate were matched within approximately 100 update cycles, and differences in magnitude were matched within approximately 300 update cycles.

Although the representational model (with each individual representing food density at each source) also approximates the results reported with real ducks, it is less stable and less realistic than the non-representational model. It is less stable in that there was much greater variability in the proportions of ducks at each source after the point at which the non-representational simulation had reached a steady state. Various non-realistic behaviors were observed in the simulations of the representational model. For example, since ducks were driven by global rather than local representations of the environment, once a duck had decided to switch food sources, it would ignore new food appearing nearby in order to move to the other source.

The key point is that in implementing a representational model, behaviors for moving about in the world (and for avoiding unrealistic behaviors like the one just described) must be devised. However, the non-representational model demonstrates that extremely simple rules can both provide the behaviors necessary for moving about in the world and account for the complex phenomena of probability matching.

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