CHAPTER 5

FRAMING OUR THOUGHTS: ECOLOGICAL RATIONALITY AS EVOLUTIONARY PSYCHOLOGY'S ANSWER TO THE FRAME PROBLEM

TIMOTHY KETELAAR
University of California at Los Angeles

PETER M. TODD
Max Planck Institute for Human Development

Abstract. Decision makers challenged by real-world adaptive problems must often select a course of action quickly, despite two computational obstacles: There is usually a vast number of possible courses of action that can be explored, and a similarly vast number of possible consequences that must be considered when evaluating these options. Thus, decision makers routinely face the *frame problem*: how to focus attention on adaptively relevant information and how to keep this information set small enough that the mind can actually perform the computations necessary to generate adaptive behavior. By identifying simple, effective heuristics that work within the computational and informational constraints of an organism and still result in adaptively adequate behavior, the new ecological rationality perspective within evolutionary psychology suggests how intelligent agents can overcome this frame problem. In this chapter we show how ecologically rational psychological mechanisms can address two challenges derived from the frame problem: 1) Using the example of sequential mate choice, we demonstrate that a satisficing information search strategy can lead to good decisions using only a limited amount of information; and 2) We argue that emotions can guide information search, by focusing the computational mind on precisely that information which is most useful for making decisions that lead to good outcomes over the long run.

H.R. Holcomb III (ed.), Conceptual Challenges in Evolutionary Psychology, 179–211.

We further describe how a bottom-up approach to studying ecological rationality, which first identifies simple heuristic decision-making components and then builds more sophisticated cognitive modules out of these components, can generate fruitful new directions for psychological scientists attempting to illuminate the structure of our evolved computational minds.

I. THE WISE BRAHMIN AND THE CHESSBOARD: HOW SEEMINGLY SIMPLE CALCULATIONS CAN REQUIRE MORE COMPUTATION THAN OUR MINDS CAN HANDLE

There is a story of an ancient rajah of India who wished to reward his royal adviser, a wise Brahmin, for inventing the game of chess (see Kasparov, 1997). When the rajah asked what he would desire for compensation, the Brahmin motioned to the grid of the 8x8 chessboard and requested that a single grain of wheat be placed on the first square of the board. He asked that the rajah's servants then double the amount of wheat on the second square and continue doubling the amount of wheat (i.e., 4 grains on the third square, 8 on the next, etc.) until all 64 squares on the chessboard had been covered. The rajah was perplexed by the Brahmin's seemingly simple request and asked him whether he indeed desired only grains of wheat—albeit in continuing doubled amounts on consecutive squares of the chessboard—as his compensation? The Brahmin replied, "Yes," and the deal was set.

A day later the rajah's senior mathematician informed him that they were having trouble granting the Brahmin's demands. By the time his servants had arrived at the 21st square of the chessboard they required over one million (1,048,576 to be exact) grains of wheat, and by the 30th square (still not quite half finished) they needed more than 10 billion grains of wheat to satisfy the rajah's promise to the Brahmin. According to the senior mathematician's calculations, to continuously double the amounts of wheat across all 64 squares of the chessboard would require more wheat than the kingdom, indeed the entire world, could produce in countless millennia of bountiful harvests.

The point of this story is not that one should distrust their advisers, but rather that problems that appear quite simple and straightforward at first glance can lead to computations on humanly unmanageable scales. Many of the human capacities we most take for granted—

vision, language, finding a mate, or deciding which strategy to play in a competitive bargaining game—involve problems that can potentially involve a vast number of possible inferences. In this chapter we explore what evolutionary psychology has to offer in explaining how the finite human mind can cut through this computational thicket and arrive at reasonable solutions to a variety of information processing problems that appear to involve considerably more resources than our computational minds have to offer.

The computational mind's dilemma

Some cognitive scientists (e.g., Fodor, 1995; Haugeland, 1995; also Baumgartner & Payr, 1995) have argued that the traditional computer metaphor of the mind, instantiated in artificial intelligence (AI) in particular, runs smack into the following dilemma: How can successful decision-making be achieved under conditions of limited time and knowledge? This dilemma has come to be called the *frame problem* (McCarthy & Hayes, 1969; Pylyshyn, 1987; Ford & Pylyshyn, 1996). This dilemma manifests itself in many domains of human computation where the number of potentially relevant inferences that can be drawn far outpaces the human mind's capacity to evaluate them. From the perspective of evolutionary psychology, a central information-processing dilemma concerns how to "frame" a problem with a limited set of inferences that a biologically plausible computational device (i.e., a mind) can handle. Even in cases where the mind could, in principle, generate and evaluate all possible inferences there are often severe ecological costs to attempting such computational omnipotence (see below).

Far from being a strictly conceptual puzzle for philosophers of mind, the frame problem emerges as a legitimate concern for computational modelers in a variety of real-world psychological domains. These domains include: (1) language comprehension: How do individuals actually draw appropriate inferences from the vast sea of possible interpretations of even the simplest speech acts? (see Sperber & Wilson, 1996; Chiappe & Kukla, 1996), (2) economic decision making: How do individuals actually select an appropriate strategy in a competitive bargaining game like the repeated Prisoner's Dilemma without mapping the incalculably vast decision tree of possible strategies[1] and the infinity of possible consequences? (see Rasmussen, 1994; Samuelson, 1997), and even (3) perception: How does an individual actually determine from a single retinal image which of the incomputably vast number of possible arrangements of objects in the world gave rise to this particular pattern of retinal activation? (see Pinker, 1984, 1997; Poggio, 1984). In all of these domains, drawing appropriate inferences could involve sifting through an astronomical number of relevant and irrelevant inferences. Any agent that actually attempts to locate the "optimal" conclusion in the vast haystack of alternative inferences may find itself bogged down in a sea of computation that puts it at an adaptive disadvantage compared to less omnipotent, but more computationally frugal organisms. Moreover, as one philosopher notes:

> unless some drastic preselection can be effected among the alternatives their evaluation could never be completed. This gives rise to what is known among cognitive scientists as the 'Frame Problem': in deciding among any range of possible actions, most of the consequences of each must be eliminated from consideration a priori, i.e., *without any time being wasted on their consideration....* (deSousa, 1994, p. 276, emphasis in the original)

An ecologically valid description of our evolved computational architecture must account for how intelligent agents overcome this frame problem to generate adaptive cognition.

Explosive Consequences of the Frame Problem

Philosopher and cognitive scientist Daniel Dennett (1987) describes the essence of the frame problem in a thought experiment involving a robot whose main mission in life is to survive. Suppose that its most vexing challenge at the moment is that its backup battery is in a room next door and that a time bomb is also in that room. The robot enters the room and deduces that the battery is on a wagon. It further deduces that pulling the wagon out of the room will remove the battery from the room. Although it deduces that the time bomb is also on the wagon, its limited deductive powers unfortunately prevent it from considering the further implications of pulling the wagon—along with the time bomb—out of the room and our mechanical friend is promptly blown to smithereens. Now imagine that the robot's design engineers develop what they believe will be an obvious remedy to the robot's limited deductive capacity: simply equip the robot with greater computational might such that it can deduce *all possible implications* of its alternative courses of action. Yet, this "obvious" solution, like the Brahmin's seemingly simple request of the rajah, quickly proves to be computationally intractable. Dennett (1998) notes that the imaginary robot began its mission:

> as designed, to consider the implications of such a course of action. It had just finished deducing that pulling the wagon out of the room would not change the color of the room's walls, and was embarking on a proof of the further implications that pulling the wagon out would cause its wheels to turn more revolutions than there were wheels on the wagon—when the bomb exploded (p. 42).

Even when the robot is given the additional computational power to calculate still more possible implications, it is obvious that this strategy is doomed. What gives rise to the frame problem is that:

> we need to know whether a consequence will turn out to be relevant *before drawing it.* If it is relevant and we have not retrieved it, we may act irrationally. But, if it is irrelevant and we have already drawn it, we have already wasted time... (deSousa, 1987, p. 194, emphasis in the original).

How can the human mind escape this quandary?

Two aspects of the frame problem

In Dennett's (1987) thought experiment, the cost of the robot's long-winded process of deducing implications far outweighed the benefits it could receive from considering those outcomes. There are simply too many implications to be considered, too much information to be computed. We identify this problem of *too much information,* as one aspect of the frame problem that confronts any computational device, be it a robot or a rabbit. So the first step that the human mind can take in overcoming the frame problem is to limit the amount of information used to make inferences—but will it still be possible to make good decisions with this limitation? We address this question in Section II of this paper.

A second important aspect of the frame problem emerges as Dennett's robot story continues: Faced with too many possible implications for their robot to consider (the problem of too much information), the robot engineers resolved to "... teach it the difference between relevant implications and irrelevant implications ... and teach it to ig-

http://www.springer.com/978-1-4020-0133-8

Conceptual Challenges in Evolutionary Psychology
Innovative Research Strategies
Holcomb III, H.R. (Ed.)
2001, XXIX, 401 p., Hardcover
ISBN: 978-1-4020-0133-8