Part I

Evolutionary and neural bases of JDM

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1 The evolved foundations of decision making

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Introduction

Decision making involves using information to guide behavior among multiple possible courses of action – for instance, to move in some direction, to ingest something or not. Such choices determine the way an organism makes its way in the world, and hence its degree of success in meeting the challenges of life. Evolution cannot shape individual choices one by one, but it can create information-processing mechanisms that will reliably produce particular kinds of choices – adaptive ones – as outputs in specific environments and situations that provide characteristic cues as inputs (Tooby & Cosmides, 1992; Gigerenzer & Todd, 1999). Thus, as the chief architect of successful, well-adapted behavior, evolution acts primarily on the mechanisms that produce the choices that organisms make. The study of decision making thus should build on an understanding of the evolutionary foundations of decision mechanisms.

In this chapter, we explore those foundations and how they can inform judgment and decision making research. We begin by considering the nature of the evolved components that enable adaptive decision making: capacities, building blocks, and decision mechanisms themselves. We then turn to a brief run-down of evolutionarily important choice domains. Following this, we discuss the ways that the functional, adaptive perspective on human decision making can be reconciled with the common view in the JDM world that people are mightily irrational. Next, to show how an evolutionary perspective can lead to new insights and experiments in JDM research, we go into a particular example in some detail: understanding the hot-hand phenomenon. Finally, we conclude with further directions for studying judgment and decision making by taking its evolutionary origins into account.

The evolved foundations of decision making

Minds are adapted to make appropriate decisions in the environments in which they evolved. We can think about the impact of those environments on the workings of decision mechanisms for any particular species at three broad time-scales, roughly distinct but interacting. First, the overarching demands of life that have long held in our general terrestrial environment determined the adaptive goals that much of decision making is aimed at solving. Second, the species' particular ancestral environment determined through its interaction with evolution the specific cognitive capacities that an organism can bring to bear in making adaptive decisions. And third, the current task environment that any individual faces determines what information structures are available to an organism's evolved decision mechanisms for making particular choices.

In this section we briefly expand on these ideas before delving into some of them in more detail later. To provide an example that will allow us to illustrate these different sources of environmental influence on decision making, consider the problem of deciding which of two meals to eat at a new restaurant. The decision can be made on the basis of pieces of information, or cues, that you know or can find out about each meal, such as whether each is made from local ingredients, is vegetarian, has less than your daily allotment of calories, contains macadamia nuts, and so on. Now the question is, how should these cues – of which there can be many, either in memory or available to look up externally – be processed to arrive at a decision about the meal to have? Simpler approaches would be to ignore all of this information and just rely on, for instance, whether you recognize one of the meals and not the other, or on the meal choice of a friend who has eaten at this place before. Thus, you could rely on the *recognition heuristic* (Goldstein & Gigerenzer, 1999; 2002), which says when selecting between a recognized and an unrecognized option to pick the recognized one, or you could use a *social learning heuristic* to imitate the behavior of others (Boyd & Richerson, 1985). Such simple decision mechanisms work well in a variety of domains, as we will see.

Adaptive goals

Evolutionary biology distinguishes between proximal and ultimate goals. The single ultimate goal, driving all of evolution, is reproduction – specifically, increasing the proportion of one's genetic representation in future generations. Survival is only important insofar as it leads to increased reproduction for oneself or one's kin. There are many proximal goals, some more closely related to survival, such as finding food and avoiding predators, and others more associated with reproduction, such as finding mates and protecting offspring (see the section below on adaptively important decision domains). Different species will evolve different sets of proximal goals depending on their biological setting, including the ecology they are enmeshed in and the life history they have evolved to lead. For example, for sea anemones that simply release sperm and eggs into the water, parental care is not an issue, whereas for humans with internal fertilization and few, initially helpless, offspring, it is a major adaptive concern. And for some species with parental care, the further goal of identifying one's offspring comes into play, so that care and resources can be directed toward them rather than another's offspring. The mind's "adaptive toolbox" (Gigerenzer, 2000) is filled with decision mechanisms for achieving these proximal goals, such as recognizing offspring (and which among humans can also be used for other modern tasks, such as recognition-based consumer choice).

Evolved capacities and heuristics

Some of our decision mechanisms are evolved and essentially "built-in," such as ducking when a looming object approaches; others are learned, either through individual experience or from other individuals or one's culture (but all via learning mechanisms that are themselves ultimately evolved). Many of the tools in the adaptive toolbox take the form of simple heuristics, which are rules of thumb or decision-making shortcuts to adaptive behavior that rely on little information and little cognitive processing (Gigerenzer, Todd & the ABC Research Group, 1999). Heuristics are typically composed of simpler building blocks, which in turn rely on underlying evolved capacities, all of which have been shaped by the species' evolutionary interaction with particular environment structures. We now briefly consider each of these components of the adaptive toolbox in reverse order, from capacities to building blocks to heuristics.

Capacities There are many evolved capacities that decision mechanisms can rely on, and different species will have different sets. Some important classes of capacities include: perception (e.g. tracking moving objects, orienting to sounds); search (e.g. exploring to find resources, staying in a local area to exploit found resource patches); learning (e.g. one-trial learning of dangerous objects, operant conditioning, imitating others); memory (e.g. recognizing individuals or names, recalling important features of objects, forgetting unnecessary information); and social intelligence (e.g. cooperating with kin or others, tracking status and reputation, identifying with a group). This list is far from complete, but expanding it to include what adaptive capacities a particular species has can help us uncover what heuristics and other behavioral mechanisms it may be able to use.

Building blocks Decision heuristics can be constructed from building blocks, including ones that guide the search for information or choice alternatives (or both), that stop that search process, and that make a decision based on the results of the search. Building blocks themselves draw on an organism's evolved capacities: for instance, "search for recognition knowledge" is a building block of the recognition heuristic that employs the ability to recognize objects encountered in the past. The simpler a building block is, the easier it may be to combine with others and the more widely it may be used. Different building blocks, like the heuristics they compose, will perform better or worse in particular environments.

The first well-studied category of building block comprises those that control the search for the information or alternatives upon which decision making strategies act (Gigerenzer, Dieckmann & Gaissmaier, forthcoming). These building blocks for guiding search, whether across alternatives or information, are what give search its direction (if it has one). For instance, the search for informative cues on which to make a decision can be simply random, or in order of some measure related to their usefulness, or based on memory for which cues worked previously when making a similar decision. Simple quick heuristics incorporate search building blocks that do not use extensive computations or knowledge to figure out where to look for what they need. The recognition heuristic, for example, employs a search building block which simply says to search for recognition of the objects being considered.

The next important class of building blocks serves to stop the decision maker's search. To operate within the temporal constraints imposed by the environment, search for alternatives or information must be terminated before too long. And to operate within the computational limitations of organisms, the method for determining when to stop search should not be overly complicated. For example, the recognition heuristic's stop-search building block specifies that information search should be ceased as soon as the recognized-or-not information about each object has been retrieved – no other information is sought. Another simple stopping rule is to cease searching for information and make a decision as soon as the first cue or reason that favors one alternative is found (leading to so-called *one-reason decision making* – Gigerenzer & Goldstein, 1996; 1999), which may involve checking multiple cues before the first discriminating one is found. (The recognition heuristic's stopping rule stops search whether or not the recognition information discriminates between the options, making it even faster.) These and other related stopping rules do not need to compute an optimal cost–benefit tradeoff for how long to search; in fact, they need not compute any costs or benefits at all. For search among alternatives, a related approach is to use a stopping rule based on an aspiration level, ceasing search as soon as an alternative is found that satisfies that aspiration (Simon, 1956; for applications of such stopping rules in mate search, see Todd & Miller, 1999; Hutchinson & Halupka, 2004).

Finally, once search has been guided to find the appropriate alternatives or information and then been stopped, a third type of building block can be called upon to make an inference (or choice) based on the results of the search. These decision rules can also be very simple and computationally bounded, for instance using only one cue or reason, whatever the total number of cues found during search (Bröder, forthcoming). Such single-cue decision making does not need to weight or combine cues, and so no common currency between cues need be determined. The recognition heuristic uses the single recognition cue to make its choice in favor of the recognized option.

Heuristics Heuristics are where the rubber meets the road, or where the mind meets the environment, by making the decisions that guide action in the world. They process the patterns of information available from the environment, via their building blocks based on evolved abilities, to produce the agent's goal-directed behavior. Thus the recognition heuristic processes the patterns of objects that are recognized or unrecognized as a consequence of one's experience with the environment interacting with one's recognition abilities, to yield recognition-based decisions. Because heuristics, rather than capacities or building blocks, act directly on the environment, they are under the most direct pressure to be adaptive, and are also the first components of the adaptive toolbox to change under that pressure (whether via learning or evolution). Thus, it is at this level that we expect to see the closest fit between mind and world, the hallmark of ecological rationality.

Information structure in the environment

The patterns of information that decision mechanisms operate on can arise from a variety of environmental processes, including physical, biological, social, and cultural sources. Some of these patterns can be described in similar ways (e.g. J-shaped distributions of criterion values or cue usefulness – see Hertwig, Hoffrage & Sparr, forthcoming), others depend on particular domains (e.g. the degree to which a resource environment is seen as auto-correlated – see Wilke & Barrett, 2009), and still others arise through systematic interactions between individuals and domains over the course of the individual's life history (Wang, Kruger &

Wilke, 2009). Here are some of the different types of environment structure that impact on a species' moment-to-moment decision making (as well as on its proximal goals and evolved decision mechanisms).

Patterns of information from the physical environment (e.g. daily light/dark cycles and three-dimensional movement patterns – Shepard, 2001) have had the longest impact on evolving behavior. Many of these patterns can be characterized by cue validities (how often particular cues yield accurate decisions), redundancies (correlations between different cue values), and discrimination rates (how often particular cues distinguish between alternatives, regardless of their accuracy). The distribution of particular events (such as whether rain is common or rare) also influences the mechanisms that people use to reason about them (McKenzie & Chase, forthcoming). Similar patterns can be exploited in biological environments comprising members of other species in roles of predators, prey, and parasites; for instance, the distribution of cue success (combining validity and discrimination rate) can be used to categorize different species (Berretty, Todd & Martignon, 1999; cf. Bergert & Nosofsky, 2007). Furthermore, the spatiotemporal patterns of items, including how they are spread across patches such as fruits clustered on bushes, can determine what search heuristic will work best for deciding when to stop search or when to switch from one patch to the next (Hutchinson, Wilke & Todd, 2008; Wilke *et al.*, 2009).

Social environments are also critically important, especially for humans. We can use heuristics to make ecologically rational decisions about other people as potential mates, based on the sequential pattern of people we have previously encountered (Todd & Miller, 1999), or about other people as potential coalition partners, based on our own and others' levels of strength (Benenson *et al.*, 2009) or the available reputational information (Hess & Hagen, 2006). Much of the information we use in decision making also comes from others, including via friends or other social contacts, which can create useful patterns in knowledge. For instance, because people tend to discuss noteworthy items, such as the tallest buildings, biggest cities, richest people, and winningest teams, patterns of recognition in individual memory can be successfully exploited by the recognition heuristic mentioned earlier (see also Pachur *et al.*, forthcoming). Recognition knowledge is also given prominence in group decision making (Reimer & Katsikopoulos, 2004).

Environment structures can also arise over time in cultures, or be deliberately created by institutions, to influence the behavior of others. Cultural systems such as age-at-marriage norms provide an example: Billari, Prskawetz & Fürnkranz (2003) used an agent-based model in which norms were used as an agent's built-in constraint, such as that marrying happened within a specific age interval rather than during the full course of that agent's life. In their simulations, age-at-marriage norms stabilized in the population and persisted in the long run. This shows that norms can be important in shaping the life of an individual and provide a simple guide to decision making in an otherwise complex environment. In modern institutions, direct design of rules for behavior is sometimes felicitous, as when governments design structures that work well with our evolved decision mechanisms, such as defaults that get more citizens to donate organs (Johnson & Goldstein, 2003), or traffic laws for intersection right-of-way set up in a hierarchical manner that matches our one-reason decision mechanisms (Bennis *et al.*, forthcoming). In other cases, institutions create environment structures that do not fit well with people's decision mechanisms, and instead can cloud minds and lead to poor choices. For instance, casinos make people think the chance of winning is much greater than it really is by filling the environment with cues of easily obtained resources (Bennis *et al.*, forthcoming), and store displays and shopping websites crowded with products and information on their features, and even dating websites with vast numbers of available partners and information on them, can draw consumers in but subsequently lead to information overload and choices that people may not be happy with (Fasolo, McClelland & Todd, 2007; Lenton, Fasolo & Todd, 2008).

Shaping goals, tools, and behaviors

To summarize, the structure of the environment can influence an organism's proximal goals, the toolbox of capacities, building blocks, and heuristics that the organism relies on, and the decisions that the organism makes as it encounters its world. But it is not exactly the *same* environment that impacts at these three points: the ancient environment in which the organism's ancestors evolved shaped its goals and tools, while the environment it currently inhabits affects its present decisions. Thus, it is important to distinguish between past and present environments when considering how decision mechanisms evolved, for the former may act in the latter (Tooby & Cosmides, 1992; Haselton *et al.*, 2009).

Adaptively important decision domains

Scientists studying the evolution of behavior are concerned with the adaptive problems and selective pressures our ancestors encountered in their environments, the psychological mechanisms that evolved to help them solve those problems, and the way those evolved mechanisms function in current environments (Buss, 2008). Consequently, evolutionary scholars stress the role of domain-specificity in the functional organization of the mind and that human cognition is not well understood when seeing it as a general-purpose problem solver (Cosmides & Tooby, 1994). These two key principles have an important implication for the study of human decision making, namely, that researchers must pay attention to the kinds of decision-making domains that were evolutionarily important, as it was within those adaptive problem domains where domain-specific decision mechanisms got adapted to particular environment structures (which may or may not any more match the statistical regularities of modern environments; see above). Typically, these adaptive problems domains cluster around decision-making areas such as finding food and shelter, finding a mate, problems of parenting and kinship, and cooperation. For the purpose of this chapter, however, we will focus on how these decision-making problems relate to the level of the individual and the level of the social group.

Evolutionarily important decision-making problems at the level of the individual

Evolutionary trajectories through different environments produce varying life histories across and within species – essentially, ways that they make their living – and these in turn yield different proximal goals. For instance, for a simple organism that is not social and does not take care of its offspring, its main objectives may be to find food, avoid being someone else's food, and find a mate. Evolution will also have shaped its nervous system to implement decision mechanisms to reach these goals. The gaze heuristic, for instance, can be of help in all three tasks: to intercept an object passing overhead, move so as to maintain a constant visual angle to that object. In pursuit of prey (and sometimes of mates), fish and insects try to maintain a constant angle of bearing relative to their target so that they will eventually catch it (see Gigerenzer, 2007). The opposite strategy works for avoiding being captured and eaten: escaping by moving so as to increase the angle of bearing. Other heuristics will be adaptive for other aspects of these goals, such as categorizing objects into prey, predators, or potential mates.

Many examples of ecologically rational decision-making mechanisms in humans are to be found when the individual has to meet its caloric requirements for survival and navigate itself in a harsh and dangerous environment. Scheibehenne, Miesler & Todd (2007), for instance, could show that a simple lexicographic strategy is as good as more complex models in predicting what kind of lunch choices people make when having to choose among an item set of 20 different lunch options. Saad & Russo