

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

(1996) investigated stopping rules in people searching for suitable habitats and found that most participants don't have constant, but rather adaptive thresholds when determining when to stop acquiring more information, and that they used a core attribute heuristic to simplify the amount of calculation required for their threshold-based stopping policy.

The experiments on human foraging behavior that we discuss below highlight another area of navigational decision making – here in the form of simple patch-leaving rules for patch departure decisions – in which heuristics are adapted to specific resource environments (Wilke, 2006; Hutchinson, Wilke & Todd, 2008). Depending on how resources are distributed across patches, these patch-leaving heuristics perform really well, but often utilize only a single cue such as the number of resource items that have been found so far or the time the forager has spent searching this particular patch. In some instances, these evolved spatial and navigational decision-making mechanisms may even differ between men and women. New *et al.* (2007) looked at how men and women search for fruits, vegetables and other traditionally gatherable food resources when tested at a local farmer's market. Participants were tested on both their spatial memory and their navigational skills in pointing to food resources of various caloric densities after they spent time walking around at the market. Consistent with the proposed theory that a sexual division in ancestral foraging labor selected for gathering-specific spatial mechanisms, women outperformed men both in memorizing the earlier encountered food locations as well as their ability to correctly point to these locations. The higher the caloric intake rate of the food resource was, the better women were in remembering the location and pointing toward it.

*Evolutionarily important decision-making problems
at the level of the social group*

For organisms that care for their offspring and live in social groups, such as humans, there are additional basic proximal goals, including protecting offspring, forming coalitions, achieving status, and finding a mate. The adaptive toolbox of a social species contains a repertoire of social heuristics for solving these kinds of proximal goals.

Detecting who is kin or not was a recurring feature of our evolutionary history. Not too surprisingly, then, humans possess an array of decision-making mechanisms dedicated to both the detection of kinship as well as the interaction with kin. Lieberman, Tooby & Cosmides (2007) studied the evolved decision-making mechanisms that humans have to assess

genetic relatedness. They theorized that human kin detection mechanisms must have a way of computing a kinship index that corresponds to the genetic relatedness between the self and the other (familiar) individual. Multiple empirical tests on more than 600 subjects showed that the kin detection system apparently uses two distinct cues to compute genetic relatedness: the familiar other's perinatal association with the individual's biological mother and the duration of sibling coresidence. Such cues for genetic relatedness are also important in grandparental decisions in how many resources they invest in their grandchildren. Everything else being the same, research has shown that maternal grandmothers invest more in grandchildren than other grandparents do and that grandparents invest more in daughters' children than in sons' children, as the associated uncertainty about their genetic relatedness to their grandchildren is minimized (e.g. Euler & Weitzel, 1996; Michalski & Shackelford, 2005).

Once kinship is detected or assumed to be present, it can affect the outcome of social decision-making scenarios. Wang (1996a; b) and Wang & Johnston (1995) revisited the hypothetical life-death decision problem known as the Asian disease problem in which subjects have to choose among two medical treatment plans for 600 anonymous people (see Tversky & Kahneman, 1981). Until then, this line of research on the framing effect had been used as a seeming irrationality in human decision-making behavior, as research subjects tend to go with the less risky medical treatment plan when the decision scenario is framed as saving lives, but switch to the more risk-seeking medical plan when the scenario is framed in terms of lives lost. Wang and colleagues argued that subjects might have had difficulties reasoning in such a novel and naïve group context. Over evolutionary time, humans lived in much smaller groups, about 100–150 individuals (see Dunbar, 1993), where, unlike modern environments, the presence of kin was very common. When Wang and colleagues administered a modified version of the Asian disease problem to research subjects – a version where group decisions varied by no more than 6 or 60 lives (i.e. an evolutionary typical small-group context) – the framing effect disappeared.

Forming powerful coalitions that extend beyond mere kinship was perhaps a central feature of the environment of evolutionary adaptedness, as coalition formation enhanced survival and reproductive success. How human decision makers form these coalitions has recently been studied in an experimental group setting by Benenson and colleagues (Benenson *et al.*, 2009). In a computerized competitive game, humans showed a systematic, intuitive strategy for coalition formation based on their own and others' level of strength. When participants were strong (i.e. had a high likelihood of winning all of the game points by themselves), they

mostly competed alone (so that later rewards would not have to be shared with others). At intermediate strength, they would often line up with a stronger and/or friendlier opponent, and when they were weakest, participants tended to go for small but guaranteed rewards. Most participants exhibited a threshold heuristic for ceasing to compete alone and permanently switching to a coalitional strategy at an intermediate probability of winning (e.g. centered around 40–50%). The researchers point out that this pattern resembles coalition formation patterns in male chimpanzees, leading them to speculate about the possibility of an evolved coalition formation heuristic with phylogenetic roots going back 5–6 million years.

Searching for appropriate social partners presents another decision-making challenge: there could always be a better person to select as a mate, or form a friendship or coalition with, somewhere in the future. How can you decide when to stop searching and stick with the current person? Here, Herbert Simon's (1955; 1990) notion of a satisficing heuristic is applicable: an aspiration level is set for the selection criterion being used, and the search for alternatives is stopped as soon as the aspiration is met. Simple mechanisms can be used to set the aspiration level in the first place, such as checking the first few alternatives and taking the best value seen in that set as the level to aim for in further search (Todd & Miller, 1999). But social search situations usually have the added complication of being two-sided or mutual, which means the searchers must convince others that they are worthy of being chosen in return, whether as mates or friends or partners. This additional challenge can be solved by the searchers learning their own value or rank position within their pool of fellow searchers and using this self-knowledge to determine how high they should aim their search aspirations (Kalick & Hamilton, 1986). Todd & Miller (1999) presented a range of simple heuristics that do this in the mating realm, learning one's mate value through the acceptances and rejections encountered during an "adolescent" dating period. Evidence that people use such aspiration-adjustment heuristics has been found via population-level demographic measures (Todd, Billari & Simão, 2005) and in laboratory experiments of sequential choice involved in speed-dating (Beckage *et al.*, 2009).

Finally, imitation heuristics, such as copying the behavior of successful group members, can be a fast road to learning how to provide for one's family as well as how to achieve status (Boyd & Richerson, 1985; Richerson & Boyd, 2004). Again, each of these proximal goals can be split up into sub-goals, such as the ability to attribute mental states to others and to infer what their intentions are (see Baron-Cohen, 1995).

Rational vs. irrational vs. evolved decision making

The common view among researchers studying judgment and decision making is that human reasoning is biased through our use of often inappropriate heuristics (Tversky & Kahneman, 1974; Kahneman & Tversky, 1996), and that people are consequently irrational in much of what we do (Ariely, 2008). But how can this be, if we evolved to make adaptive decisions? There are at least two answers to this seeming quandary. First, the instances of irrational behavior we sometimes see people engaged in may be outweighed by the benefits of avoiding more costly errors. Second, our decision heuristics that seem inappropriate in specific modern settings may be designed by evolution for use in different environmental situations, where they perform well. We now explore each of these possibilities in turn.

When adaptive benefits outweigh irrational costs – error management theory

People can make adaptive decisions using simple mechanisms and reliable cues, but they are still at risk of making errors. Although completely eliminating errors is rarely possible in the context of decision making, it is possible to systematically commit one type of error over another. For example, imagine the problem of reliably identifying a recurrent ancestral danger such as detecting a poisonous snake. For any given relevant percept (e.g. a long serpentine object), a judgment must be made: snake present or no snake present? Because of the direct fitness consequences of being bitten by a poisonous snake, it is better to have a low threshold for inferring that long slender objects are snakes, and to jump at every snake (and some snakey sticks) you encounter, than to require too much evidence and potentially get bitten and die. As both types of error cannot be minimized at the same time, asymmetries in the costs of the two types of error should lead systems to be biased in the direction of the least costly error. This is the underlying logic of error management theory (Haselton & Buss, 2000; Haselton & Nettle, 2006), an approach that applies evolutionary logic to signal detection theory.

Whereas signal detection theory never considered the ancestral fitness costs of errors, error management theory can inform us about adaptive decision making in both past and present environments. Error management theory proposes that a cognitive system will be biased in a particular direction depending on the recurrent cost asymmetry associated with inferences in that problem domain. While error management biases often increase overall error rates and thus appear irrational, they minimize

overall fitness costs. So far, error management theory has been successfully applied to a variety of novel perceptual biases (e.g. that humans, and monkeys, underestimate the arrival time of objects directly approaching them in both the auditory and visual modalities: Schiff & Oldak, 1990; Ghazanfar, Neuhoff & Logothetis, 2002), biases involved in dealing with threats from pathogens and out-group members (e.g. physical overresponse to disease threats or the rejection of food that is actually edible: Rozin & Kalat, 1971; Nesse, 2001), mating decisions (e.g. men's overperception of women's sexual interest: Haselton, 2003), and beliefs about the intentions of others (Barrett *et al.*, 2005). In the latter experiment, Barrett *et al.* showed subjects animations of a variety of social interactions such as chasing, playing, and courting. Overall, subjects were very accurate in judging a variety of intention patterns, but also had a systematic false alarm bias such that they inferred chasing when chasing was not present. The authors speculate that this pattern could reflect a universal error management bias designed to avoid the high costs of missing malevolent intentions in others. Thus, error management theory demonstrates that decision biases may not be proof for the irrationality of the human mind, but rather evidence of solutions that minimize particularly costly errors and produce an adaptive net benefit to the decision maker (for a review see Haselton *et al.*, 2009).

When evolved mechanisms act in appropriate environments – ecological rationality

Another seeming irrationality occurs when decision mechanisms that work fine in appropriate environments are invoked in inappropriate environments and the principle of ecological rationality is violated. Ecological rationality describes the match between structure and representation of information in the environment on one side, and decision-making algorithms such as heuristics on the other. Whenever this match exists, heuristics can perform well (Todd & Gigerenzer, 2007; Todd, Gigerenzer & the ABC Research Group, forthcoming).

An evolutionary approach to decision making, however, can push the insight gained from ecological rationality even further. This can be seen, for example, when the current environment in which the decision-making algorithm is applied differs from the statistical regularities of the past environment in which the mind evolved. In these cases the proper information environment for a decision-making algorithm may not occur as frequently anymore in modern environments or simply be absent (cf. Sperber, 2004). As an example, consider a series of experiments on human foraging behavior. Hutchinson, Wilke & Todd (2008) investigated

how humans time their search behavior when resources are distributed in patches (i.e. areas with a high density of the resource surrounded by areas with low resource density). Participants were not only required to make a decision on where to forage, but also on how long they should forage in a particular patch as resources diminished (Charnov, 1976). Behavioral ecologists have long studied this problem of patch time allocation (Bell, 1991) and looked at so-called patch-leaving strategies (i.e. simple decision mechanisms) in varying environmental resource contexts (Iwasa, Higashi & Yamamura, 1981). Biologists realized that different resource environments call for different patch-leaving strategies, as the resource environments can differ in how resources are distributed across patches. For instance, the number of resource items across patches can either be quite similar (evenly dispersed distributions), completely random (Poisson distribution), or some patches may only contain a few items while others will be very resource rich (aggregated distributions). The results of the human foraging experiments showed that participants also applied patch-leaving rules that were particularly appropriate for aggregated environments in other types of environments (e.g. those with evenly dispersed and Poisson distributions). Hence, subjects behaved adaptively in one class of resource environment, but did not adapt very well to other environments (see Hutchinson, Wilke & Todd, 2008).

As Wilke (2006) argues, the finding may not be that puzzling once one considers that aggregation in space and time, rather than dispersion, is likely to have been the norm for most of the natural resources humans encountered over evolutionary time. Species of plants and animals rarely, if ever, distribute themselves in a purely random manner in their natural environment, because individual organisms are not independent of one another: *whereas mutual attraction leads to aggregation for some species, mutual repulsion leads to regularity (dispersed environments) in others* (Taylor, 1961; Taylor, Woivod & Perry, 1978). *Most often, these deviations from randomness are in the direction of aggregation, because aggregation offers considerable benefits such as a common habitat, mating and parenting, or the benefits of group foraging* (Krause & Ruxton, 2002). Since humans have been hunters and gatherers for about 99 percent of their history (Tooby & DeVore, 1987), it could well be that our evolved psychology is adapted to assume such aggregated resource distributions as the default. Thus, participants in the foraging experiments may have behaved in an evolutionarily rational manner by assuming that the resource distribution was the same as what our minds became attuned to over our species' phylogenetic history (cf. Houston, McNamara & Steer, 2007a).

As we will see next, the idea that humans expect aggregation – autocorrelation in space and time – can help to explain why apparent misconceptions of probability, such as hot-hand thinking, may not be as irrational as it has been considered so far.

Profiting from an evolutionary perspective: the case of the hot-hand phenomenon

As an example of the benefits of taking an evolutionary perspective for understanding a particular domain of decision making, we now turn to a phenomenon that has generated much debate and a number of proposed explanations with little overarching conceptual coherence. A large body of research in psychology suggests that people have difficulty thinking about randomness and often perceive systematic patterns in series of independent events (e.g. Falk & Konold, 1997; Nickerson, 2002; Oskarsson *et al.*, 2009). One such purported “deviation” in the perception of binary sequences – labeled the *hot-hand fallacy* – was identified in observers' predictions about the likely outcomes of basketball shots (Gilovich, Vallone & Tversky, 1985). Both basketball players and fans judged that a player's chance of hitting a shot was greater following a successful shot than a miss. That is, they had an implicit assumption of “streaks” or “runs” in players' shooting success and perceived hits to be positively autocorrelated, or clumped. However, when Gilovich, Vallone & Tversky (1985) analyzed the actual data on which subjects' predictions were made, they found that the shots were statistically independent (cf. Avugos *et al.*, unpublished).

What we will call hot-hand thinking (to separate it from the negative connotation of “fallacy”) has also been found in other judgment domains such as betting markets (Camerer, 1989), finance (Hendricks, Patel & Zeckhauser, 1993), or gambling behavior (Croson & Sundali, 2005). Most previous studies, though, have examined relatively artificial and evolutionarily novel environments, and no overarching theory or predictive pattern regarding where hot-hand thinking will or will not be found has been agreed upon.

A variety of explanations for hot-hand thinking have been proposed. The original explanation by Gilovich, Vallone & Tversky (1985) was that people bring an assumption of “representativeness” to the data and mistakenly infer an autocorrelation that extends beyond the short sequence sampled. Others suggested that hot-hand thinking results from overgeneralization of patterns that people have learned from experiences of real world distributions where there are streaks, but that do not apply to cases such as free throws and coin tosses (Gilden & Wilson, 1995, 1996; Ayton & Fischer,

2004), or that streaks indeed occur in some sport disciplines (e.g. Clark, 2003; Smith, 2003). Burns (2004) suggested that hot-hand thinking is “adaptive” in that streaks can be valid cues for deciding whom to pass the ball to and that using these cues can contribute to the team goal of scoring more (see also Raab, Gula & Gigerenzer, unpublished). Consequently, prior research viewed hot-hand thinking either as a byproduct of some cognitive mechanism or a process which might be “adaptive,” in some cases, but is often misapplied as in the case of basketball shots, coin tosses, and other sequences of independent, binary events.

Wilke & Barrett (2009) started their research on hot-hand thinking from an evolutionary perspective, arguing that prior research had begun from the wrong place in asking why people are so bad at thinking about random (independent) events. The right question instead is to ask, what are people thinking about when they contemplate sequential events? Wilke & Barrett explicitly proposed that hot-hand thinking is an evolved cognitive adaptation to a world where clumps are the norm (rather than the exception) and that it may represent a psychological default to expect clumps in a wide variety of domains. From an evolutionary point of view, cognitive skills should be adapted to the kinds of fitness-relevant problems faced by our ancestors, not to modern contexts like sports or gambling. Truly independent and random events are likely to have been relatively rare in ancestral environments. In nature, clumps are frequently found, because animals and plants tend to cluster together due to common habitat and seasonality preferences, predator avoidance, mating, and other factors (see above). There are good reasons to suspect that some degree of clumpiness was common for most of the natural resources that humans would have encountered over evolutionary time. The existence of decision-making adaptations to exploit such clumps could therefore be expected on evolutionary grounds, and the features of hot-hand thinking seem well suited to exploit environment structure in this way.

To test whether hot-hand thinking is culturally influenced or is more universally applied as an evolutionary perspective would suggest, Wilke & Barrett (2009) developed a computer game that simulated sequential search for resources and used it to compare undergraduate subjects from UCLA with Shuar hunter-horticulturalists from Amazonian Ecuador. During the simulated search, individuals were shown whether resources were present or absent in a series of locations and were asked to predict whether there would be resources in the next spot. The distribution of resources in all experimental conditions was completely random. However, different conditions used different types of resources. Some were natural resources such as fruit and bird nests, others were modern-day resources such as parking spots and bus stops.

Participants showed a high level of hot-hand thinking across the board in both cultures, consistent with the idea that it is an evolved psychological default. Furthermore, two additional patterns emerged that support an evolutionary basis: first, more hot-hand thinking appeared for natural resources than for the artificial, man-made resources, suggesting that it may indeed have evolved to aid our ancestors in their foraging pursuits. Second, when comparing decisions about coin tosses and foraged fruits, the authors found that Shuar hunter-horticulturalists showed equal levels of hot-hand thinking for both, whereas UCLA students were at about the same level as Shuar subjects for fruits, but lower for coin tosses. This suggests that familiarity arising from lifetime experience with the truly random nature of coin tosses might have helped the students learn away from their evolved default.

These findings are important, because they may help explain a persistent feature of seeming human irrationality: the tendency to see streaks that are not actually there. If the evolutionary argument proposed by Wilke & Barrett (2009) is correct, then hot-hand thinking is not the systematic irrationality that it is typically viewed as, but exists because of the benefits of detecting streaks and clumps in a world where such patterns frequently occurred and continue to occur – outside of the narrow domain of sports and gambling. As explained by error management theory, the fitness costs of misperceiving illusory streaks were smaller during the course of evolution than the costs of making wrong predictions in environments where streaks naturally occurred.

Conclusions: how to evolutionize JDM research

The decision mechanisms generating the human behavior that we study did not arise through mathematical derivation of the optimal way to process information and make choices; rather, they evolved through successive tinkering within a framework of biological and cultural constraints to meet, as well as possible, the adaptive challenges that face us (and faced our ancestors) in particular environments and domains. In this chapter we have illustrated how the field of judgment and decision making will benefit from adding this evolutionary perspective to its research approach.

First, by exploring decision domains that are more evolutionarily important than, for instance, lotteries – domains such as food choice, mate choice, resource exploration, and child-rearing – researchers in judgment and decision making will be able to speak to, and draw more heavily from, results in other neighboring fields. Many of the choice domains that we considered in this chapter are very actively studied in

other scientific disciplines and the cross-fertilization with those fields could inspire new surges in decision research (e.g. in biological anthropology – see Winterhalder & Smith, 2000; in behavioral ecology – see Hutchinson, Wilke & Todd, 2008; in animal behavior – see Houston, McNamara & Steer, 2007b; in primatology – see Heilbrunner *et al.*, 2008). In other words, decision researchers will benefit from studying things that are important to people (and other animals), not just important to economists or psychologists – and an evolutionary perspective is a good guide to identifying what those relevant domains are (see also Kenrick *et al.*, 2009).

Second, studying adaptive important domains implies using more real-world-relevant tasks, not just conducting more-or-less circumscribed and contrived laboratory studies. That is, we should take up the charge put forth by Egon Brunswik in his call for representative design of experiments over 50 years ago (e.g. Brunswik, 1955; see also Dhami, Hertwig & Hoffrage, 2004). This will provide results on human-important tasks that are more likely to generalize to human behavior in the real world. We should also study more of that real-world behavior itself, through field experiments and observations. For instance, recent work in marketing, studying the daily choices that consumers make, has achieved greater theoretical understanding and predictive power by considering the evolved mechanisms underlying those choices (Saad, 2007; Miller, 2009).

However, exploring important decision-making domains via real-world human behavior will also lead us to more examples where the environmental setting may not match what the decision mechanisms are designed to do. Such instances of modern-day mismatch (e.g. choosing restaurant meals that are patently unhealthy) may seem like a challenge to the evolutionary perspective – but they can actually be predicted and explained through this perspective more effectively than through others (cf. Kurzban, 2010). More challenging aspects to adopting an evolutionary perspective for studying decision making include the necessity to become familiar with an additional well-developed knowledge domain, the required discipline of making and testing evolutionarily inspired predictions rather than just applying evolutionarily plausible explanations after the fact, and the effort to constrain those predictions with multiple sources of data (e.g. comparative, paleontological, etc.) to increase their predictive power. But as we have aimed to show in this chapter, the benefits outweigh these costs.

An evolutionarily informed study of judgment and decision making will incorporate a perspective that sees the mind and world fitting together through the action of evolved capacities, building blocks, and heuristics, along with learned and culturally inherited decision mechanisms, all of

which guide us to make good decisions adapted to particular environmental circumstances. By studying the mind in the appropriate environment structures to which it is attuned, we will be able to focus not on our irrationality, but on our evolved ecological rationality.

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