Past and present environments: The evolution of decision making

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The human mind is filled with evolved decision mechanisms designed to meet adaptively important goals. In this article we lay out a framework for studying those mechanisms from the perspective of evolutionary psychology, emphasizing the importance of multiple influences of the environment on shaping the decision strategies and their operation. These strategies often take the form of simple heuristics constructed from building blocks that draw on evolved capacities, all of which fit to particular information structures in the environment. We illustrate these ideas with two examples of heuristics used in important adaptive domains: deciding when to leave a resource patch, and predicting when a sequence of events will stop or continue.

Ambientes pasados y presentes: la evolución de la toma de decisiones. La mente humana está repleta de mecanismos evolutivos de toma de decisiones diseñados para alcanzar importantes metas adaptativas. En este artículo se traza un marco para el estudio de dichos mecanismos desde la perspectiva de la psicología evolucionista, haciendo énfasis en la importancia de las numerosas influencias que el ambiente tiene en la formación y funcionamiento de las estrategias de decisión. Estas estrategias adoptan a menudo la forma de heurísticos sencillos construidos a partir de componentes que, a su vez, emanan de capacidades que han evolucionado, encajando con determinadas estructuras de información del entorno. Aquí se ilustran estas ideas con dos ejemplos de heurísticos empleados en dominios adaptativos importantes: decidir cuándo abandonar un área con recursos y predecir cuándo una secuencia de eventos se detendrá o continuará.

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 Buss, 2008). Different species will evolve different sets of proximal goals depending on their biological setting including the ecology in which they are enmeshed and the life history they have evolved to lead (e.g., Stearns, 1992). 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. Members of species with parental care are faced with the goal of identifying one's offspring, so that an individual's care and resources are directed toward genetic kin rather than another's offspring. The mind is filled with domain-specific decision mechanisms that have evolved by natural selection for achieving these proximal goals,

and evolutionary psychology is dedicated to identifying and understanding those mechanisms (Todd, Hertwig, & Hoffrage, 2005). The purpose of this paper is to lay out a framework for how these decision mechanisms can be studied within evolutionary psychology, emphasize the often-neglected role of the decision environment when studying human behavior and cognition, and provide an illustrative example of how an evolutionary perspective can help us detect more of the adaptive decision making capacities humans possess.

Adaptive decision making

Decision making is using information to guide behavior among multiple possible courses of action—to move in some direction, to ingest something or not, or to favor one romantic partner over another. 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. Thus, 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, our species' particular ancestral environment created selection pressures that led to specific cognitive capacities that allow an organism to make 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.

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 so that a decision is reached about the meal to have? A simple approach would be to ignore all of this information, and just rely on whether you recognize one of the meals and not the other. In this case, 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. This simple rule of thumb works well in a variety of domains, but not in others —that is, it has evolved to be used in those environments to which it fits, and furthermore its use in a current environment will only be adaptive if that environment is structured such that recognition knowledge is a reliable indicator of appropriate things to eat.

Evolved capacities, heuristics and environment structures

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 mind's evolved psychological mechanisms 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 (see Gigerenzer, Todd, and 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 mind's evolved set of decision mechanisms in reverse order, from capacities to building blocks to heuristics, and look at the specific role of information structure in the decision environment.

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 (see Gigerenzer, Todd, and the ABC Research Group, 1999). 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 previously encountered. 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.

Heuristics

Heuristics make 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 mentioned earlier 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 mind's set of evolved decision mechanisms that 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 (e.g., Todd & Gigerenzer, 2007a).

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 of information quality, others depend on particular domains. Here are some of the different types of environment structure that impact a species' moment-to-moment decision making (as well as 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. 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). 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, Hutchinson, Todd, & Czienskowski, 2009).

Social environments are also critically important, especially for humans. We can use heuristics to make ecologically rational decisions, for instance, 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 other's levels of strength (Benenson, Markovits, Thompson, & Wrangham, 2009). 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, Todd, Gigerenzer, Schooler, & Goldstein, in press).

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 and Fürnkranz (2003) used an agent-based model in which norms where 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). Under particular assumptions of the intergenerational transmission of norms, these 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.

Hence, 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, Bryant, Wilke, Frederick, Galperin, Frankenhuis, & Moore, 2009).

Ecological and evolutionary rationality

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, 2007a, 2007b; Todd, Gigerenzer, and the ABC Research Group, in press). 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 in a challenging and potentially dangerous environment (e.g., Todd & Gigerenzer, 2007b).

An evolutionary approach to decision-making, however, can push the insight gained from ecological rationality even further. This happens 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 and 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) and humans 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 example, 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 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, Woiwod, & 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% 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.

As we will see in the next section, the idea that humans expect aggregation—auto-correlation in space and time—can also help

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 hot-hand phenomenon

As another 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; Oksarsson, Van Boven, McClelland, & Hastie, 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 et al. (1985) analyzed the actual data on which subjects' predictions were made they found that the shots were statistically independent (cf. Avugos, Raab, Bar-Eli, Czienskowski, & Köppen, under review).

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) 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 has been agreed upon regarding the presence or absence of hot hand thinking across various contexts.

A variety of explanations for hot hand thinking have been proposed. The original explanation by Gilovich et al. (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 (e.g., 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. 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 and 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 and 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 suggests), 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 all tasks in both cultures, suggesting that this type of reasoning is an evolved psychological default. Furthermore, two additional patterns emerged that support an evolutionary hypothesis: First, more hot hand thinking appeared for natural resources than for the artificial, man-made resources, suggesting that it may have indeed 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.

Conclusions

Evolution has equipped our minds with a set of evolved psychological mechanisms to guide us through particular types of tasks in specific adaptive problem domains. When mind and world fit together, the evolved capacities, building blocks, and heuristics

enable us to make accurate choices because the decision mechanisms can exploit the structure of information in the environment. We saw this in the examples covered here of patch-leaving decisions and related decisions about streaks governed by hot hand thinking. An evolutionary cognitive psychology approach can help us uncover the ecological rationality of these decision mechanisms and allow us to understand in which environments, past and present, they may work well.

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