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# Cognitive Bias

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### Glossary

**Bounded rationality** The principle that organisms have limited resources, such as time, information, and cognitive capacity, with which to find solutions to the problems they face.

**Cognitive bias** Systematic error in judgment and decision-making common to all human beings which can be due to cognitive limitations, motivational factors, and/or adaptations to natural environments.

**Ecological rationality** The principle that there is a match between the structure of information in the environment and the judgment and decision-making strategies of humans and other organisms.

**Heuristic** Judgment or decision-making mechanism or cognitive shortcut that relies on little information and modest cognitive resources.

## Heuristics and Biases: A Short History of Cognitive Bias

In the early 1970s, Amos Tversky and Daniel Kahneman introduced the term 'cognitive bias' to describe people's systematic but purportedly flawed patterns of responses to judgment and decision problems. A term search for 'cognitive bias' in the Social Sciences Database of ISI Web of Knowledge reveals close to 4000 hits covering the past 35-year period and an exponential increase in the usage over time, suggesting that the term 'cognitive bias' has since gained significant influence in the psychological and social science literatures.

Tversky and Kahneman's research program – the heuristics and biases program – addressed the question of how people make decisions given their limited resources. The program was inspired by Herbert Simon's principle of bounded rationality. In the late 1950s, Simon attempted to oppose the idea of classical rationality, which was concerned mostly with the formalization of normative solutions to judgment and decision-making problems through probability theory and statistics, with the idea of bounded rationality, which addressed the specific constraints faced by agents in their environments. For example, humans have only limited time, information, and cognitive capacity to decide which mate to choose, food to eat, or house to buy, and so may have to rely on simple decision strategies or heuristics to make their decisions. The heuristics and biases program followed the bounded rationality principle by attempting to identify the specific constraints or biases associated with human judgment and decision-making.

The heuristics and biases program was inspired by research on perceptual biases, and proposed that the human cognitive system like the perceptual system was designed to make inferences about the external world based on imperfect cues that could lead to errors in some situations. The program thus generated a straightforward and productive research paradigm, which can be described as follows. First, participants were presented with a reasoning problem to which corresponded a normative answer from probability theory or statistics. Next, participants' responses were compared with the solution entailed by these norms, and the systematic deviations (biases) found between the responses and the normative solutions were

listed. Finally, the biases were explained as the consequence of the use of heuristics or simple cognitive principles. Using this strategy, researchers in the heuristics and biases program have produced an extensive catalog of norm violations. We present a partial list in Table 1 that spans the judgment and decision-making, social, and memory research domains. Naturally, the goal was to provide explanations of these violations due to reliance on a small set of cognitive principles, the most popular judgment and decision mechanisms proposed being *representativeness* (a judgment is based on how much the hypothesis resembles available data), *availability* (a judgment is based on how easily an example can be brought to mind), and *anchoring-and-adjustment* (a judgment is based on a specific value or anchor and then adjusted to account for other factors).

The heuristics and biases program represents the most influential psychological research program to emerge in the last 40 years, and its merit lies in showing the shortcomings of classical economic approaches and the value of a bounded rationality perspective on understanding human judgment. The heuristics and biases program has, however, been criticized. First, researchers have argued that there are no unequivocal norms for defining rational judgments and decisions. For example, there are different concepts of probability espoused by statisticians and philosophers that imply different norms, which makes deviations from one hard to interpret as error or bias. Second, the program has been criticized for presenting only vague models of human reasoning. For example, the representativeness, availability, and anchoring-and-adjustment heuristics proposed by Tversky and Kahneman do not provide quantitative predictions of people's judgments and it is often unclear which heuristic is applied under which condition. Third, the heuristics and biases program has been criticized for focusing on people's initial responses to judgment problems rather than providing opportunity for learning from experience. For example, some anomalies to classical decision theory are eliminated if people have substantial experience with a decision problem. Similarly, many classic paradigms in this tradition involve participants' responses to situations described in word vignettes, which are not ecologically valid and thus may offer inadequate insights about everyday decision-making.

**Table 1**    Examples of common cognitive biases

| Cognitive bias | Short description |
|---|---|
| Confirmation bias | The tendency to selectively search for or interpret information in a way that confirms one's preconceptions or hypotheses |
| Conjunction fallacy | The tendency to assume that specific conditions are more probable than a single general one |
| Endowment effect | The tendency that people often demand more to give up on an object than they would be willing to pay to acquire it |
| Fundamental attribution error | The tendency to overemphasize personal factors and underestimate situational factors when explaining other people's behavior |
| Gambler's fallacy | The tendency to think that future probabilities are changed by past events, when in reality they are unchanged (e.g., series of roulette wheel spins) |
| Halo effect | The tendency for a person's positive or negative traits to extend from one area of their personality to another in others' perceptions of them |
| Hindsight bias* | A memory distortion phenomenon by which with the benefit of feedback about the outcome of an event, people's recalled judgments of the likelihood of that event are typically closer to the actual outcome than their original judgments were |
| Hot-hand fallacy* | The expectation of streaks in sequences of hits and misses whose probabilities are, in fact, independent (e.g., coin tosses, basketball shots) |
| Illusory correlation | The tendency to identify a correlation between a certain type of action and effect when no such correlation exists |
| In-group bias | The tendency for people to give preferential treatment to others they perceive to be members of their own group |
| Mere exposure effect | The tendency by which people develop a preference for things merely because they are familiar with them |

Asterisks refer to examples that are discussed in the main text.

This view echoes well Egon Brunswik's argument for the study of the mind by relying on the informational cues present in natural environments.

## Ecological Rationality: Putting Cognitive Biases in an Environmental Context

One fundamental criticism of the heuristics and biases program is that it has severely neglected the ecology of judgment and decision processes. The principle of bounded rationality is deeply associated with the idea that cognitive systems are fundamentally adapted to their environments – either through individual learning or by design through natural selection. Simon illustrated this with a metaphor: mind and environment as blades of a pair of scissors. Similar thoughts have been espoused by a number of other theorists. For example, Roger Shepard saw human vision as reflecting regularities of the physical world. John Anderson advanced the idea that memory is structured so as to mimic the probability of information occurring in the world and thus being needed by the organism.

In the late 1990s, Gerd Gigerenzer, Peter Todd, and the ABC Research Group presented a research program – the fast and frugal heuristics program – that extended the principle of bounded rationality and gave new breadth to the idea of cognitive bias. The fast and frugal heuristics program emphasized the principle of ecological rationality, that is, how the success of reasoning strategies depends on the structure of the environment. A good example of this principle is demonstrated by the United Parcel Service (UPS) Right Turn Policy: UPS, an international shipping company, delivers millions of packages every year in numerous delivery trucks. The right turn policy involves carefully mapping out routes for all deliveries to reduce the number of left-hand turns each truck makes, which helps reduce accidents as well as save fuel, thus maximizing overall profits. Naturally, this strategy works well in the United States and other countries where traffic keeps to the right. One would predict, however, that the right turn policy would have the opposite results in countries, such as England, India, or Hong Kong, where people drive on the left.

The fast and frugal heuristics program has proposed an alternative research paradigm to the heuristics and biases' one. The program starts by analyzing the statistical structure of a specific task environment people face and then – based on the analysis – derives attributes of the cognitive models of reasoning that perform well in that environment. In sum, this program holds that exploring the characteristics of the environment will contribute to our understanding of what reasoning processes people follow and when and why these processes work well.

According to the fast and frugal heuristics program, a cognitive bias is the tendency to solve problems using a particular cognitive tool or heuristic. Crucially, it sees the selection of a particular heuristic not necessarily as the product of cognitive limitations but rather as a bet on the part of the organism about the structure of the environment in which it finds itself. One metaphor that guides the fast and frugal heuristics program is that of the mind as an adaptive toolbox of simple decision mechanisms, a repertoire of strategies, with each strategy tuned to a particular environment. A model of mind based on an adaptive toolbox is, therefore, boundedly rational in the sense of relying on few cognitive resources, and ecologically rational in the sense of being tuned to characteristics of natural environments.

Some have suggested that the differences between the Heuristics and Biases and the Fast and Frugal Heuristics programs are not substantive, boiling down to a disagreement between those that stress that the human mind is fallible and those who claim that it is often accurate. One clear contribution of the Fast and Frugal Heuristics program has been, however, to emphasize the role of environment and specify the statistical properties of environments that make particular cognitive biases or heuristics successful. In addition, the focus on ecological rationality has spurred new approaches that emphasize the role of environment and sampling in determining adaptive behavior. Specifically, recent approaches are devoted to understanding the role of sampling in generating

bias with less focus on the cognitive apparatus and more on environmental stimuli. For example, people's risk judgments of low probability events are often inflated. One possibility is that such bias is due to selective memory retrieval. However, an unbiased memory may also produce inflated judgments of risk due to biased media coverage of natural catastrophes and accidents. Current and future work on cognitive bias is concerned with the role of biased sampling in both the external environment and the internal cognitive apparatus.

## Evolutionary Rationality: Understanding Why Cognitive Biases Occur

The concept of ecological rationality describes the match between structure and representation of information in the environment on one side, and the simple decision-making algorithms such as heuristics on the other. Whenever this match exists, heuristics can perform well. Evolutionary rationality holds, however, that it is important to consider the match between mind and the *past* environments in which the mind evolved. In other words, evolutionary rationality attempts to sketch the evolutionary origins of cognitive bias.

Some evolutionary scientists have followed the Heuristics and Biases program approach of using errors to study cognitive bias. The underlying principle behind such research strategy is that while people can make rapid adaptive decisions using simple and reliable cues, they are still at risk of making errors. However, these researchers have tried to introduce the role of costs to theories of cognitive biases. The argument goes that eliminating errors altogether is rare, if ever possible, but the costs associated with certain errors may lead organisms to systematically commit one type of error over another. This principle is at the heart of error management theory – a theory that applies evolutionary logic to signal detection theory. Imagine the problem of reliably identifying a recurrent danger in the environment such as poisonous snakes. For any given relevant percept (e.g., a long slender object on the ground), one must make a decision: snake present or snake absent. Because of the dire consequences of being bitten by a venomous snake, it is better to have a low evidentiary threshold for inferring that long slithering objects are snakes so as to identify every snake you encounter, than to require too much evidence and occasionally incur a costly surprise. Because both types of errors cannot be minimized at the same time, asymmetries in the costs of two types of errors (false positives and false negatives) should lead systems to be biased in the direction of the least costly error.

Examples of such biases can be found in auditory perception. For example, listeners perceive tones with rising intensity to change faster than equivalent tones falling in intensity – an effect termed auditory looming. Auditory looming has also been found to occur in nonhuman primates and is well explained in an error management theory framework. The enhanced saliency of rising intensities associated with approaching objects causes listeners to reliably underestimate object arrival time. The bias occurs with tones but not broadband noise showing some specificity for sound that provides reliable single-source information and made almost exclusively by biological organisms. Of course, any time a bias affects perception of the physical environment, there are risks of misapplying it to irrelevant objects that could lead to any variety of costly errors. The degree to which this is true will largely determine how advantageous the bias will be, and thus its impact over evolutionary time. In the case of auditory looming, the costs of false alarms (e.g., wasting time by being ready too early) are relatively low compared to the costs of misses (i.e., not being prepared for an approaching object). The difference in these costs allows for the selection of a bias that causes people to systematically overestimate a reliable auditory cue of movement toward a listener.

## Examples of Research on Cognitive Biases

In this section, we introduce two examples of research on cognitive bias. The first example focuses on search in the external world and how people's perceptions of events or their co-occurrence may be biased toward frequent, natural distributions. In this example, cognitive bias arises from experimenters observing an organism's behavior or judgments in environments that are very atypical compared to those experienced across phylogenetic and/or ontogenetic time. The second example focuses on biases in internal search from memory and emphasizes that cognitive bias may occur both due to cognitive limitations and motivational factors. For example, an individual's inaccurate recall of poor past performance may be due to poor memory and/or a motivation to preserve a positive view of the self.

### Foraging, Hot Hands, and the Structure of the Environment

The work of Andreas Wilke and colleagues on human foraging behavior in patchy environments, illustrates that an awareness of ancestral conditions can be key to understanding human decision-making strategies. When resources are distributed in patches (i.e., areas with a high density of the resource surrounded by areas with low density), animals are required not only to make decisions on where to forage, but also on how long they should forage in a particular patch as resources diminish. Biologists have studied simple decision mechanisms that solve this problem of patch time allocation and identified resource environments where these mechanisms work well. Different patch-leaving strategies are necessary because resource environments differ in how resources are distributed across patches. The number of resource items within a patch can either be similar (evenly dispersed distributions), completely random (Poisson distributions), or some patches may only contain a few items while others will be very resource rich (aggregated distributions). Wilke and colleagues tested how well humans can adapt their patch-leaving behavior when faced with such resource distributions in a computerized foraging game. The results showed that participants applied patch-leaving rules that were particularly appropriate for aggregated environments also in other types of environments (e.g., those with evenly dispersed and Poisson distributions). Were research participants ecologically *irrational*?

This finding is less 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. 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. Since humans have been hunters and gatherers for a very long part of their history, it could well be that our evolved psychology is adapted to assume such aggregated resource distributions as the default. Thus, participants in the foraging experiment might have behaved *evolutionarily rationally*.

The idea that humans expect aggregation in space and time also helps to explain why apparent misconceptions of probability, such as the hot-hand fallacy, may not reflect fundamental shortcomings of the human mind but rather adaptation to the statistical structure of natural environments. The hot-hand fallacy occurs when research subjects expect lucky streaks in hits and misses in everything from basketball to coin tosses when in fact the probabilities of events are independent. When a basketball player hits many shots in a row, for instance, the natural expectation is that he has a 'hot hand' and will shoot another successfully. People are often surprised to discover that this strong intuition does not square with the reality that the success of the next shot is determined independently from the shot before it.

The foraging example presented above hints at an explanation for the hot-hand phenomenon based on limited experience with evolutionarily novel events like coin tosses, and gambling that involve random events. Instead, one can ask about the structure of objects and events surrounding important adaptive problems faced by our ancestors, and what kinds of adaptations might have been shaped by selection. Evolutionary behavioral scientists would argue that many of these – plants, animals, human settlements, and even weather – would have been organized in an aggregated, clumpy fashion – not perfectly at random (independent) like those in Las Vegas. Thus, the default human expectation is aggregation, clumpiness, and nonindependence. To explore this hypothesis, Wilke devised additional computer tasks in which the subject could forage for fruits, coin tosses, and several other kinds of resources, and present them to American undergraduates and a South American indigenous population of hunter-horticulturalists (the Shuar). In each population, subjects exhibited the hot-hand phenomenon for all resource types, despite the fact that the resources were distributed randomly by the computer. The one exception found was for coin tosses for the American students only for which the hot-hand expectation was reduced though not altogether eliminated. This suggests that the expectation of aggregation in space and time may be the psychological default that is overcome only through extensive experience with truly independent random phenomena like coin tosses. This runs in contrast to the original explanation offered for the hot-hand phenomenon – that it is attributable to biased sampling by the mind – and instead suggests it is a consequence of the minds' adaptation to the distribution of resources in the natural environment.

## Memory Biases: Cognitive and Motivational Determinants

Would humans be better off if we had been blessed with superior cognitive abilities, such as unfailing memories? One view on the rather limited cognitive capacities of the human mind is that limitations, such as forgetting, have functional significance. Some researchers, like John Anderson, have suggested that the function of memory is not simply to store information, but rather provide relevant information in specific situations. According to this view, the human memory system is organized such that it facilitates the retrieval of information that is recent, frequent, and relevant to the current context. In other words, memory is designed to provide the information we are most likely to need. Many man-made information systems are built in such way. For example, computer applications usually incorporate a timesaving feature as follows: When a user tries to open a document file, the applications presents a 'file buffer,' a list of recently opened files from which the user can select. Whenever the desired file is included on the list, the user is spared the effort of searching through the file hierarchy. For this device to work efficiently, the application must provide the user with the desired file. It does so by 'forgetting' files that are considered unlikely to be needed on the basis of the assumption that the time since a file was last opened is negatively correlated with its likelihood of being needed now. In other words, such a system has a bias toward information that is likely to be needed.

Although memory systems are very often efficient, they can sometimes fail because forgetting and sensitivity to contextual knowledge may lead to systematic error. The hindsight bias is one of the most frequently cited and researched cognitive biases in the psychological literature. Hindsight bias is a type of memory distortion in which, with the benefit of feedback about the outcome of an event, people's recalled judgments are typically closer to the outcome of the event than their original judgments were. Research on hindsight bias is particularly important because it is a ubiquitous phenomenon and one with potentially detrimental consequences in applied settings, such as law and medicine.

In the 1970s, Baruch Fischoff was concerned with professionals such as clinicians' or politicians exaggerated feeling of having known all along how patients' recovery or elections were going to turn out. To study this issue empirically, Fischhoff asked participants to assess the probabilities of various possible outcomes concerning upcoming events, for example, President Nixon's historic trips to China and the Soviet Union (e.g., Pres. Nixon will meet Chairman Mao; Pres. Nixon will announce that the trip was a success). After the trips, participants were asked to recall their predictions. Results showed that participants tended to exaggerate what they had known in foresight.

There are two common experimental designs that have been used in the psychological literature. In the *memory* design, participants first make judgments concerning some stimuli, then receive feedback on some or all of the items, and are finally asked to recall the original judgments. In the *hypothetical* design, participants first receive feedback concerning some or all of the items and are then asked to say what they would have estimated had they not been given feedback. Empirical results using either design have shown that recalled or hypothetical estimates are commonly biased toward the feedback information.

At present, there is no single theory that can explain all patterns of data and moderator variables that have been studied in laboratory or real-world settings (e.g., expertise, experimental materials). One potential reason for this is that multiple processes are involved in producing the effect. In fact, there is largely consensus that the bias is multiply determined, and involves both cognitive and motivational factors.

Regarding cognitive factors, the prevalent idea is that both processes of retrieval and reconstruction play a role. For example, when reporting the original judgment participants are likely to both try to retrieve the specific memory of the event as well as reconstruct the original judgment process. Accordingly, the hindsight bias effect can occur by new information (feedback) biasing (1) the retrieval cues used to query memory for the original judgment, (2) the reconstruction of the judgment process, (3) or both. This view also suggests a prominent role for inhibition processes. Accordingly, research shows that individuals with strong inhibitory deficits have more difficulties inhibiting feedback about the outcome of an event from entering working memory and thus show increased hindsight bias. As expected, this is particularly the case when the correct response is either in sight or accessible in working memory at the time of the attempt to recall one's original response.

In addition, there is evidence that hindsight bias may serve motivational goals. For example, people seem to change the perceived probabilities of events so that negative events appear inevitable as a way to mitigate disappointment and personal blame. However, this seems to occur mostly in situations people can control and in situations that are unexpected, suggesting that such phenomena should be interpreted in the light of people's attempts at preparing for future events. In other words, these forms of hindsight bias can be seen as arising from the use of a sense-making process, whereby people integrate all they know about a topic into a coherent mental model. In this light, human memory is not so much designed to accurately reconstruct the past as it is to make sense of it to better deal with the future.

See also: Cognition and Personality; Defense Mechanisms; Judgment.

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