

INSIGHTS

PERSPECTIVES



COGNITION

When persistence doesn't pay

Rats, mice, and humans all invest more time in a foraging task than is in their interest

By Sarah F. Brosnan^{1,2}

People routinely make bad decisions. Far from being random, however, these bad decisions are often predictable, occurring reliably in specific contexts (1–3). One set of such suboptimal decisions are cognitive biases, wherein individuals make decisions that predictably violate rationality or their own best interests without a logical reason for doing so (4). One such bias is the sunk cost bias, in which indi-

viduals invest more time or resources in an outcome than it is worth given the potential gain, presumably because they focus on hindsight evaluation of irrecoverable costs rather than prospective gains (5). On page 178 of this issue, Sweis *et al.* (6) report a clever experiment demonstrating the sunk cost bias in rats, mice, and humans. The findings also provide insight into why results from previous studies have been so variable.

Cognitive biases can be substantial impediments to optimal decision-making and are

costly to individuals and society. Comparing responses across different species is key to understanding how these biases evolved and will help to both predict when they will manifest and offer suggestions as to how to offset them. However, determining how the sunk cost effect evolved has not been easy, because the bias is not consistently expressed in other species (7–9).

Studying the sunk cost bias is challenging because it is difficult to separate investment from future expectations, especially in field studies. Lab experiments can more easily distinguish between these factors, but lab experiment setups can differ substantially across species, particularly between humans and other species, making comparisons difficult.

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When foraging, animals must decide whether to continue in the current patch or move on. Staying too long is an example of the sunk cost bias, which Sweis *et al.* demonstrate in rats, mice, and humans.

Sweis *et al.* overcome the latter problem by using the same basic procedure, based on a foraging task, across all three species.

In their experiment, subjects had a limited time budget during which they rotated through four reward options that differed in how well the subjects liked them (subjects showed consistent preferences across the study). At each transition, subjects first had to decide whether to commit to the available option or move to the next option. If they committed, they could not get the reward until they had waited for a predetermined period of time; the time remaining was indicated to the subject throughout the waiting period. Subjects could leave at any point during the waiting period, without penalty, and move to the next option in the rotation.

A subject not showing the sunk cost bias should leave quickly if a less preferred reward is paired with a long wait time. Nonetheless, subjects of all species were more committed to sticking with their choices than their preferences warranted, thus demonstrating a sunk cost bias. Indeed, this bias grew stronger the longer they waited; that is, it increased with increasing investment. However, it was unaffected by the time spent making the choice initially. Supplemental work indicates that there is a distinct decision phase during which sunk costs do not accumulate, even when this phase is not explicitly included as a separate period in the experimental design. The authors argue that this is evidence for two independent valuation processes, one assessing whether to accept an offer and the other—the one that is susceptible to sunk costs—assessing whether to continue investing in the choice.

The evidence for two different valuation systems working together offers the possibility of a comprehensive explanation for the sunk cost effect that integrates cognition, behavior, and neural architecture across species and contexts. Moreover, these results hint at some of the reasons for the previous disparate results. Perhaps wait times were not long enough to get past the assessment period, or, more speculatively, decisions may change if subjects do not know how long they must wait or if they are otherwise engaged in an active task (such as lever pressing) during the waiting period.

A key reason for Sweis *et al.*'s success is the degree to which they worked to provide a relevant, comparable methodology. They chose a context, foraging, that had ecological relevance to these species in the context of sunk costs and came up with a clever way of pro-

viding information about how much future investment remained to minimize information uncertainty. Importantly, they provided the humans and the rodents with the same procedures and information.

Of course, there were differences among species. Differences in training between the rodent labs required control tests to verify that behavior was truly the same. Humans, unlike rodents, are not consistently food motivated, and so they “foraged” for entertainment, in the form of movie clips, instead. Such adaptations to account for species-typical behavior and differing environments are nearly unavoidable in comparative work, but it is critical that the fundamental procedure is the same and that the limitations of one's study are acknowledged (10), as in Sweis *et al.* For instance, the authors chose film clips because, like the differently flavored food, they differ in value but not handling time, which allows for a direct comparison across the four choice options.

Why are we susceptible to the sunk cost bias? In some situations, it may be difficult to evaluate future costs; in these cases, past efforts can be a reasonable proxy. If this heuristic worked well enough most of the time, there would not have been strong selection pressure to evolve a more sophisticated strategy. Indeed, many human decision-making biases likely result from a trade-off between the costs of acquiring and processing information and the costs of getting it wrong (11). Understanding this evolutionary trade-off can help us to better understand why humans make the decisions that we do and, ultimately, suggest ways of improving human decision-making (12). Sweis *et al.*'s adaptable design is likely to prove helpful in future experiments investigating sunk cost biases across a variety of species and contexts. ■

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EVOLUTION

Many roads to convergence

Plant genomes highlight complex mechanisms behind evolutionary convergence

By László G. Nagy

Many plants form specialized symbiotic root structures, called nodules, that harbor beneficial associations with nitrogen-fixing bacteria in the genera *Rhizobium* or *Frankia* (see the photo). How this nitrogen-fixing root nodule (NFN) symbiosis arose repeatedly during plant evolution is an age-old mystery: It shows signatures of convergence (the repeated emergence of similarity during evolution) yet builds on similar gene sets in phylogenetically distant plants. On page 144 of this issue, Griesmann *et al.* (1) sequenced the genomes of 10 plant species to reveal the genetic correlates of the origin and loss of NFN symbiosis. Their work reveals intricate gain and loss patterns of symbiosis-associated genes, calling for new models to explain convergent evolution.

NFN symbiosis has an immense impact on plant growth and global nitrogen cycling but occurs only in four related plant orders, the Fabales, Fagales, Cucurbitales, and Rosales, collectively known as the NFN clade. Only a few phylogenetically diverse members of the NFN clade form symbiosis, making NFN symbiosis a phylogenetically patchy character (2, 3). Despite its phylogenetic patchiness, nodule formation builds on surprisingly similar gene sets (4), with some key symbiosis-associated genes, such as *NODULE INCEPTION (NIN)* and *RHIZOBIUM-DIRECTED POLAR GROWTH (RPG)*, being widely conserved across plants. Besides *NIN* and *RPG*, another 290 genes were recently found to be up-regulated in nodules of *Medicago truncatula* and *Parasponia andersonii*, two plant species that independently evolved the ability to form symbiosis. This is surprising, given that these species diverged ~100 million years ago and belong to two separate orders, the Fabales and Rosales, respectively (4). How can this level of genetic similarity be reconciled with the phylogenetic patchi-

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