ROOTS OF REASON

Our daily deliberations provoke scientific debate

By BRUCE BOWER

Suppose an astrologer offered you this advice: If a person is a Leo, then that person is brave. As a confirmed skeptic, you want to debunk such a starry-eyed notion, but how might you go about it?

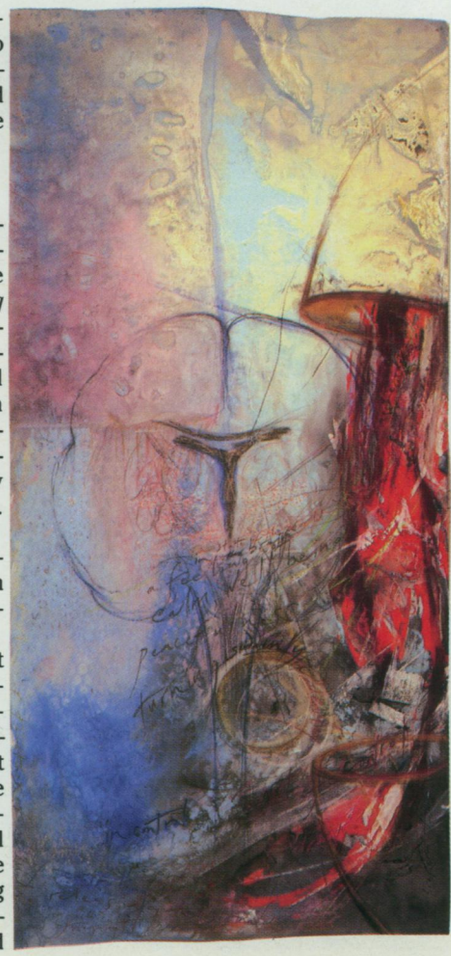
First, you would probably look for exceptions to the rule by assessing the bravery of people you know whose birthdates qualify them as Leos. Then you might look for Leos among individuals of unquestioned valor. However, the latter tactic leaves the astrologer's claim unscathed, since not all brave people need to possess the same astrological sign. A clutch of heroic Virgos, for example, could coexist with all those courageous Leos.

What's worse, you — like all people who attempt to solve an experimental version of this task — probably fail to consider the astrological credentials of cowards. A card-carrying Leo who cringes at his own shadow would clearly violate the astrologer's rule. Now consider a more down-to-earth problem. Imagine yourself as a bartender who can legally serve alcohol only to people age 21 or older. At your bar sit four customers, each quaffing a beverage. You know that one nurses a beer, another sips a soda, and an adult and a teenager make up the rest of the group. What do you need to know to determine whether your liquor license is in jeopardy?

In contrast to the astrologer's challenge, about three-quarters of those who ponder this problem in experiments correctly realize that the bartender must find out the beer drinker's age and what the teenager has in his glass.

The astrologer and bartender quandaries share an underlying structure summarized as "If *p* (in these cases, a Leo or a liquor drinker), then *q* (brave or at least 21 years old, respectively)." Yet over the past decade, an increasing number of studies has charted large differences in the ease with which people resolve various "if-then" questions. These results have inspired competing scientific reassessments of how people reason and solve problems. Moreover, related research has fueled an escalating debate over the nature of routine decision making, in which we often base judgments on ambiguous and incomplete bits of information.

One group of researchers argues that millions of years of evolution have endowed humans with a multitude of "reasoning instincts" that automatically coordinate the way we think about important day-to-day problems that echo those faced repeatedly by our Stone Age ancestors. In their view, people generally deal best with such challenges, which include finding food and mates, assessing threats, and exchanging goods and services. Much recent research has focused on a reasoning instinct that may aid in identifying individuals who cheat on social obligations, such as underage drinkers.



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Moreover, the same scientists assert that humans rely on evolved brain mechanisms to estimate the frequency with which pairs of events in our immediate surroundings occur together. Frequency judgments of this sort pave the way for relatively accurate inductions, or inferences generated from the particulars of daily life. According to this theory, decisions occur so fluidly that they get taken for granted. Take, for example the jogger who — based on many previous encounters — intuitively knows which dogs to avoid during a run. Other investigators agree that people reason in specialized ways depending on what they think about and the context in which thinking occurs. But they argue that various situations evoke sets of rules, called "pragmatic reasoning schemas," which cover a far broader range than, say, a mechanism for detecting cheaters. One proposed reasoning schema guides inferences about whether a specific event or action causes another; a second orchestrates reasoning about permitted behavior in different contexts, which includes cheater detection; and a third handles thinking about obligations in various situations.

Some scientists, however, see no need to invoke instincts or rules that specialize in solving particular kinds of problems. Instead, they theorize that individuals make specific inferences from rough guidelines, or reason deductively, by constructing "mental models" that keep track of conclusions compatible with the information at hand and any relevant background knowledge. The mental model that provides the best fit between the premises of a problem and an acceptable conclusion wins out in this approach.

In another bow to mental models, influential studies conducted over the past 20 years have focused on general principles that help us patch together decisions out of incomplete or ambiguous threads of information. Investigators of these judgmental shortcuts, or "heuristics," view the human mind as a good, yet often fallible, reasoning device that falls prey to certain "cognitive illusions," just as our senses sometimes produce perceptual illusions. From this perspective, people apply mental heuristics to single problems of concern and make little note of how frequently two events are associated with each other.

The evolutionary approach to reason sparks much passion and polemic. Two researchers at the University of California, Santa Barbara — Leda Cosmides, a psychologist, and John

Tooby, an anthropologist — have for the past decade applied Charles Darwin's theory of natural selection to their proposed revision of how scientists conceptualize human thinking. Cosmides and Tooby reject the widespread opinion among psychologists that the human brain harbors at most a few flexible mechanisms for reasoning about all sorts of problems and situations.

In fact, since the 17th century, a number of influential philosophers have proposed that people achieve rational conclusions by invoking abstract principles, or a "universal calculus" of logic embedded in the mind.

The Santa Barbara scientists instead take inspiration from early experimental psychologists such as William James, who proposed more than 100 years ago that human intelligence surpasses that of other animals because our minds include a constellation of "faculties," or "instincts," that directs learning, reasoning, and behavior.

"The human mind contains specialized mechanisms that evolved to reason about important problems posed by the social world of our ancestors," Cosmides contends. "The mind is probably more like a Swiss army knife than an all-purpose blade. It's saturated with mechanisms that solve adaptive problems well."

According to this approach, we reason most poorly when faced with problems that our evolutionary forebears never worried about, such as demonstrating that not all people born under the sign of Leo are brave. Psychologists have often tested responses to evolutionarily novel problems, a tactic that makes people look illogical and irrational, the two researchers maintain.

Cosmides and Tooby summarize their work on reasoning about social exchange in the 1992 book *The Adapted Mind.* (J.H. Barkow, L. Cosmides, and J. Tooby, editors, Oxford Univeristy Press).

Evolutionary biologists refer to social exchange as "reciprocal altruism," a fancy phrase for "I'll scratch your back if you scratch mine." Mathematical analyses of reciprocal altruism have employed the Prisoner's Dilemma, in which two players receive varying rewards and punishments for either cooperating with each other or acting selfishly. Success at this task hinges on the rapid detection of partners who fail to return favors (SN: 7/3/93, p.6).

To test whether people make special types of inferences to ferret out social cheaters, Cosmides and Tooby turned to the Wason test, a reasoning experiment introduced in 1966 by Peter Wason, a psychologist at University College, London. Volunteers administered a Wason test check the veracity of a hypothesis posed in the form of "If *p*, then *q*." Each participant views four cards that, respectively, show cases corresponding to *p*, not-*p*, *q*, and not-*q*. They are told that each card contains values for the corresponding part of the hypothesis on its opposite side.

Standard logic dictates that the rule is violated when *p* is true but *q* is false. Thus, a volunteer should turn over *p* and not-*q* (which might have *p* on its back).

For instance, one version of the Wason test asks for verification of the rule, "If a card has a D on one side, then it must have a 3 on the other side." Volunteers view four cards displaying D, F, 3, and 7, respectively. To determine if the rule has been violated, they must turn over D (corresponding to *p*) and 7 (corresponding to not-*q*.

Although Wason expected people to excel at picking out breaches of arbitrary if-then rules, he and many other researchers found that fewer than one-quarter of those tested offer logically correct answers. Most commonly, participants fail to choose the not-q card, a misstep comparable to omitting cowards from an evaluation of the claim that all Leos exhibit bravery.

Yet people detect violations of if-then rules much more easily and accurately if the situation calls for enforcement of a social contract, exemplified by "If you take the benefit, then you pay the cost," Cosmides and Tooby argue. In these instances, finding people who cheat on the contract assumes paramount importance. Even if such cheating occurs in unfamiliar or bizarre situations, from 70 percent to 90 percent of volunteers accurately pick out cheaters on a Wason test, according to the researchers.

For instance, in experiments Cosmides and Tooby administered to Stanford University undergraduates, one Wason test described a fictitious tribe in which a chief called Big Kiku decrees that "If you get a tattoo on your face, then I'll give you a cassava root." Other tests presented arbitrary rules devoid of any social-exchange implications, such as "If you eat duiker meat, then you have found an ostrich eggshell."

About three-quarters of the students turned over the correct cards to determine whether Big Kiku lived up to his word. But only about one-quarter succeeded in figuring out whether arbitrary rules had been violated.

DRINKING-AGE PROBLEM

In its crackdown against drunk drivers, Massachusetts law enforcement officials are revoking liquor licenses left and right. You are a bouncer in a Boston bar, and you'll lose your job unless you enforce the following law:

"If a person is drinking beer, then he must be over 20 years old."
(If P then Q)

The cards below have information about four people sitting at a table in your bar. Each card represents one person. One side of a card tells what a person is drinking; the other side of the card tells the person's age.

Indicate only those card(s) you definitely need to turn over to see if any of these people are breaking this law.

drinking beer	drinking Coke	25 years old	16 years old
(P)	*(not-P)*	*(Q)*	*(not-Q)*

Cosmides, Tooby

An example of a Wason test.

Elaboration of these findings comes from a study conducted by Gerd Gigerenzer of the University of Chicago and Klaus Hug of the University of Salzburg in Austria. Logical responses on Wason tests involving social contracts vary with one's perspective on cheating, Gigerenzer and Hug report in the May 1992 COGNITION.

In one trial, college students searched for cheaters on the following social contract: "If an employee works on the weekend, then that person gets a day off during the week." They could turn over cards bearing the statements "worked on the weekend," "did not work on the weekend," "did get a day off," and "did not get a day off." Some participants adopted the perspective of the employer, while others took an employee's view of the situation.

When looking for cheats, most "employees" worried about whether a comrade had worked on the weekend but did not get a day off; thus, they turned over cards corresponding to p ("worked on the weekend") and not-q ("did not get a day off"), the logically correct answer to a typical Wason test. But "employers" looked for whether an employee cheated by taking a weekday off in spite of not working on the weekend; thus, they most often looked under cards corresponding to not-p ("did not work on the weekend") and q ("did get a day off"), the most logical choices given their perspective.

Another study employing Wason tests, published in the August 1993 COGNITION, also finds that adults more often solve problems that link a cost to a benefit. But one's perspective on cheating actually adds little to this effect, argue Richard D. Platt and Richard A. Griggs, both psychologists at the University of Florida in Gainesville. Good reasoning occurs most often when volunteers receive clear statements about a rule violation, such as "If you take the benefit, you *must* pay the cost," they conclude.

In Gigerenzer and Hug's study, students may have tried to figure out whether the rule about the benefits of weekend work was correct or not rather than whether a violation of the rule had occurred, the Florida researchers maintain.

Whatever the case, a specific mental mechanism keeps tabs on social contracts and stays alert for cheats, Cosmides contends.

Further Wason tests devised by the Santa Barbara researchers provide preliminary support for two additional reasoning instincts. One regulates precautions taken in hazardous situations, and the other assesses aggressive threats, such as bluffs and double crosses.

A universal network of reasoning instincts governs social exchange, Cosmides and Tooby theorize; different parts of the network emerge from one situation to another within a culture, as well as between cultures.

Keith J. Holyoak and Patricia W. Cheng, both psychologists at the University of California, Los Angeles, view a reasoning mechanism devoted only to the costs and benefits of social contracts as far too narrow. Instead, they contend, a general set of "permission schemas," or rules, allows people to assess whether others conform to all sorts of contractual agreements, of which paying the costs for particular benefits makes up only a small part.

In permission schemas, satisfaction of a precondition bestows the right to take a regulated action. Consider the drinking-age rule. The permission schema focuses attention on the case in which the action occurs (check alcohol drinkers to make sure they meet the age precondition) and the case in which the precondition is not met (make sure teenagers are not drinking alcohol). These cases correspond to *p* and not-*q* cards on a Wason test — the logically correct responses.

Moreover, a set of "obligation schemas" allows individuals to judge situations in which satisfaction of a precondition imposes a duty to take a certain action, according to the UCLA investigators. For instance, participants typically perform well on Wason tests that describe an obligation for those who treat AIDS patients: "If you clean up spilled blood, then you must wear rubber gloves." The test mentions no specific benefit for which one must pay a cost, Cheng notes.

Permission and obligation schemas work in complementary ways that can explain Gigerenzer and Hug's observation of perspective effects on reasoning, Cheng and Holyoak maintain. For the rule "If an employee works on the weekend, then that person gets a day off during the week," employees concentrate on the employer's duty following weekend work and their own rights to a day off, whereas employers focus on employees' duty to meet a weekend-work obligation and the bosses' right to deny a day off to those who hadn't done so. This leads to contrasting responses on a Wason test, the UCLA researchers hold.

Unconscious reasoning instincts favored by Cosmides and Tooby cannot explain the "explicit," or conscious, strategies that foster human creativity, the ability to imagine alternative solutions, and planning for the future, Holyoak adds. Explicit reasoning often deals with problems far removed from our evolutionary past, he asserts. Its purpose appears to revolve around "helping us adapt the environment to us."

"Evolution has tuned the way we think to frequencies of co-occurrences, as with the hunter who remembers the area where he has had the most success killing game."

— Gigerenzer

Evolved reasoning instincts allow us to think about the world in ways that give rise to explicit reasoning, Cosmides responds.

As this debate proceeds, some researchers simply reject the need for content-specific rules in favor of more flexible "mental models" that help individuals choose the best available solution to Wason tests or other reasoning tasks.

Philip N. Johnson-Laird, a psychologist at Princeton University, has for more than a decade promoted mental models as keys to deductive reasoning.

His latest research, conducted with Princeton colleague Malcolm I. Bauer and published in the November 1993 PSYCHOLOGICAL SCIENCE, finds that certain types of diagrams help people track the various elements that make up a complex problem and, in turn, to reason about that problem more successfully.

In one test, 24 college students grappled with the following mind-bender:

Raphael is in Tacoma or Julia is in Atlanta, or both.

Julia is in Atlanta or Paul is in Philadelphia, or both.

What follows?

Not surprisingly, fewer than half of the students deduced a valid conclusion, such as "Julia is in Atlanta, or both Raphael is in Tacoma and Paul is in Philadelphia."

Yet three-quarters of another group of 24 students solved the same problem when the researchers supplied a diagram that showed shapes corresponding to Julia and her cohorts, each of which could fit into a similarly shaped slot corresponding to the appropriate city. These reasoners also reached their conclusions more quickly than those who simply read about the potential whereabouts of the puzzle's far-flung protagonists.

Visual images apparently reduce the amount of verbal information that reasoners must keep track of and speed up the process of inference, Johnson-Laird argues.

Enigmatic puzzles such as that above may seem bizarre, but they magnify a common problem in reasoning, he adds: As the number of possibilities suggested by a problem increases, so does confusion in reasoners. In high-pressure situations, this can lead to disastrous decisions. For instance, Johnson-Laird points out, just prior to malfunctions at Three Mile Island, operators concluded that a leak caused the high temperature at a relief valve and overlooked the possibility that the valve was stuck open.

Reasoning aids that, like Johnson-Laird's mental models, offer a framework for problem solving influence much research on how people reach routine decisions. Although these handy mental shortcuts prove indispensable for making sense of often confusing snippets of information, they also lead judgments astray in a number of situations, according to many studies.

"People use mental approximations to understand an uncertain world," argues Amos Tversky, a psychologist at Stanford University. "As a result, we make certain types of errors in judgment."

In a 1974 SCIENCE article, Tversky and psychologist Daniel Kahneman of the University of California, Berkeley, described 11 "cognitive biases" produced by mental heuristics. A cascade of related research by Tversky, Kahneman, and others soon followed.

Gigerenzer, joined by Cosmides and Tooby, now challenges the widespread emphasis on reasoning shortcuts and

their shortcomings. Gigerenzer, building on a theory proposed by German psychologist Egon Brunswick in the 1960s, views the human brain as an "intuitive statistician" immersed in unconscious calculations of the frequency with which pairs of phenomena occur together in one's immediate surroundings.

"Evolution has tuned the way we think to frequencies of co-occurrences, as with the hunter who remembers the area where he has had the most success killing game," Gigerenzer asserts. "When we take frequency thinking into account, we can make cognitive biases disappear."

This dispute reflects a division that has existed in statistics and probability theory for more than 300 years. Bayesians – named for 18th century British mathematician Thomas Bayes – consider probability a measure of subjective certainty about single events; for instance, "I'm 70 percent certain that my favorite baseball team will win today." In contrast, frequentists view probability as the long-term recurrence of events; say, "My favorite baseball team won 7 out of its last 10 games when today's pitcher started the game."

People reason cognitive biases right out of existence when faced with frequentist rather than Bayesian versions of the same problem, Gigerenzer contends.

Exhibit number one: the "conjunction fallacy." In one test conducted by Tversky and Kahneman, volunteers read about a single, outspoken woman described as a former philosophy major who as a student took part in antinuclear protests and still holds liberal political views. Participants almost always consider it more probable that the woman is both a bank teller and an activist in the feminist movement than that the woman is simply a bank teller. But the probability of a conjunction of the two circumstances cannot exceed the probability of one of those circumstances occurring by itself. Thus, the woman more likely works at the bank – period.

Yet according to Gigerenzer, about three out of four people correctly solve this problem when they read about the woman and respond to a frequentist question: How many of 100 people who fit this description are bank tellers, and how many are bank tellers and active in the feminist movement?

In the October 1991 PSYCHOLOGICAL REVIEW, Gigerenzer also takes on the "overconfidence bias." When asked a general-knowledge question, such as "Which city has more inhabitants, Hyderabad or Islamabad?" groups of volunteers tend to think they know the answer more often than they actually do. Gigerenzer and his colleagues find that after college students answer a series of such questions, they accurately estimate their total number of correct responses, even though they feel overconfident about answers to particular queries.

And in a study slated to appear in COGNITION, Cosmides and Tooby confront a cognitive bias known as the "base-rate fallacy." As an illustration, they cite a 1978 study in which 60 staff and students at Harvard Medical School attempted to solve this problem: "If a test to detect a disease whose prevalence is 1/1,000 has a false positive rate of 5%, what is the chance that a person found to have a positive result actually has the disease, assuming you know nothing about the person's symptoms or signs?"

Nearly half the sample estimated this probability as 95 percent; only 11 gave the correct response of 2 percent. Most participants neglected the base rate of the disease (it strikes 1 in 1,000 people) and formed a judgment solely from the characteristics of the test.

Cosmides and Tooby rephrased the medical problem in frequentist terms for several groups of college students. After stating the base rate of the disease, their description says that "out of every 1,000 people who are perfectly healthy, 50 of them test positive for the disease." For a random group of 1,000 people, "how many who test positive for the disease will actually have the disease?"

This version yielded a correct response from three out of four participants, the psychologists contend.

Overall, the data suggest that people automatically compute frequencies of events that occur together time and again in their environments, Gigerenzer holds. Given limited knowledge about a specific problem and a restricted amount of attention to devote to its solution, frequency estimates provide a foundation for planning and decision making.

Tversky and Kahneman take strong exception to Gigerenzer's critique. They note that their research has long distinguished between an "inside" focus on the details of a particular problem and an "outside" view of long-term frequencies in a reference class of related problems. Although the latter information greatly improves the quality of judgments, people generally ignore it in favor of an inside perspective, Tversky and Kahneman maintain.

An example of this tendency appears in the November 1993 PSYCHOLOGICAL SCIENCE. Robyn M. Dawes, a psychologist at Carnegie Mellon University in Pittsburgh, and his co-workers asked college students to provide estimates of the frequency with which their peers endorsed certain personality characteristics alone and in combinations, such as "I enjoy doing things which challenge me" and "I spend a good deal of my time just having fun."

Volunteers tended to ignore their base-rate predictions of how often students cited single characteristics and provided inflated estimates of the proportion of their peers reporting pairs of personality features, Dawes' team concludes.

"I'm sympathetic with the frequentist approach to statistics, but not to life," Tversky says. "Single-case thinking is far more common, and we see about as many errors in frequency judgments as in single-case judgments."

In one study of faulty thinking about frequencies, he notes, volunteers incorrectly asserted that more words exist that end in the letters "ing" than contain "n" as their next-to-last letter.

Mistakes inevitably occur when dealing with frequencies, Gigerenzer acknowledges. But fewer appear, he contends, if a person has experienced a representative sample of relevant co-occurrences in the environment (such as the approximate size of various cities), as opposed to less salient cues (such as the number of words harboring certain letter combinations).

The debate over single-case and frequency thinking appears destined to take some unusual turns. In an unpublished study of how people reason about causes and effects, UCLA's Patricia Cheng – a staunch critic of reasoning instincts proposed by Cosmides and Tooby – elicits support for their frequentist position.

Cheng and UCLA colleague Angela Fratianne offered volunteers feedback as they attempted to figure out a cause-effect relationship, such as whether any of three hypothetical chemicals in a fertilizer caused a fungus to grow on plant roots. Those shown data outlining the frequency of fungus growth in the absence of a particular chemical (the effect's base rate), as well the frequency in the presence of the same substance, more easily and accurately identified the fungus-fomenting culprits.

"It's plausible that people [unconsciously] use information about the frequency of an effect in the absence of a cause to test causal hypotheses," Cheng contends.

Keith Holyoak, Cheng's UCLA collaborator, downplays the role of frequency computations in reasoning, although he sees a place for mental heuristics. More important, he argues, people achieve inductive insights by relying on clusters of related rules or principles that make sense of available information in flexible ways. For example, "If it's four-legged, furry, and has a wet nose, it's a dog"; but "If it also has black rings around its eyes and emerges from the woods, it's a raccoon."

A series of computer simulations supporting this theory appears in a 1986 book coauthored by Holyoak, *Induction: Processes of Inference, Learning, and Discovery* (J.H. Holland *et. al,* MIT Press).

One conclusion, articulated by Amos Tversky, resonates among all researchers exploring the roots of reason. "At this point, nobody has a complete theory of judgment and decision making." □