Rationality

WHAT IT IS

WHY IT SEEMS SCARCE

WHY IT MATTERS

STEVEN PINKER

Author of the *New York Times* bestseller
ENLIGHTENMENT NOW

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To Roslyn Wiesenfeld Pinker

What is a man,
If his chief good and market of his time
Be but to sleep and feed? A beast, no more.
Sure he that made us with such large discourse,
Looking before and after, gave us not
That capability and godlike reason
To fust in us unus’d.

—Hamlet

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PREFACE

Rationality ought to be the lodestar for everything we think and do. (If you disagree, are your objections rational?) Yet in an era blessed with unprecedented resources for reasoning, the public sphere is infested with fake news, quack cures, conspiracy theories, and "post-truth" rhetoric.

How can we make sense of making sense—and its opposite? The question is urgent. In the third decade of the third millennium, we face deadly threats to our health, our democracy, and the livability of our planet. Though the problems are daunting, solutions exist, and our species has the intellectual wherewithal to find them. Yet among our fiercest problems today is convincing people to accept the solutions when we do find them.

Commentaries by the thousands have lamented our shortfall of reason, and it's become conventional wisdom that people are simply irrational. In social science and the media, the human being is portrayed as a caveman out of time, poised to react to a lion in the grass with a suite of biases, blind spots, fallacies, and illusions. (The *Wikipedia* entry for cognitive biases lists almost two hundred.)

Yet as a cognitive scientist I cannot accept the cynical view that the human brain is a basket of delusions. Hunter-gatherers—our ancestors and contemporaries—are not nervous rabbits but cerebral problem solvers. A list of the ways in which we're stupid can't explain why we're so smart: smart enough to have discovered the laws of nature, transformed the planet, lengthened and enriched our lives, and, not least, articulated the rules of rationality that we so often flout.

To be sure, I am among the first to insist that we can understand human nature only by considering the mismatch between the environment in which we evolved and the environment we find ourselves in today. But the world to which our minds are adapted is not just the Pleistocene savannah. It's any nonacademic, nontechnocratic milieu—which is to say, most of human experience—in which the modern instruments of rationality like statistical formulas and datasets are unavailable or inapplicable. As we shall see, when people are given problems that are closer to their lived reality and framed in the ways in which they naturally encounter the world, they are not as witless as they appear. Not that this gets us off the hook. Today we do have refined instruments of reason, and we are best off, as individuals and as a society, when we understand and apply them.

This book grew out of a course I taught at Harvard which explored the nature of rationality and the puzzle of why it seems to be so scarce. Like many psychologists, I love to teach the arresting, Nobel Prize–winning discoveries of the infirmities that afflict human reason, and consider them to be among the deepest gifts to knowledge that our science has contributed. And like many, I believe that the benchmarks of rationality that people so often fail to measure up to should be a goal of education and popular science. Just as citizens should grasp the basics of history, science, and the written word, they should command the intellectual tools of sound reasoning. These include logic, critical thinking, probability, correlation and causation, the optimal ways to adjust our beliefs and commit to decisions with uncertain evidence, and the yardsticks for making rational choices alone and with others. These tools of reasoning are indispensable in avoiding folly in our personal lives and public policies. They

help us calibrate risky choices, evaluate dubious claims, understand baffling paradoxes, and gain insight into life's vicissitudes and tragedies. But I knew of no book that tried to explain them all.

The other inspiration for this book was my realization that for all its fascination, the cognitive psychology curriculum left me ill equipped to answer the questions I was most frequently asked when I told people I was teaching a course on rationality. Why do people believe that Hillary Clinton ran a child sex ring out of a pizzeria, or that jet contrails are really mind-altering drugs dispersed by a secret government program? My standard lecture bullet points like "the gambler's fallacy" and "base-rate neglect" offered little insight into just the enigmas that are making human irrationality so pressing an issue today. Those enigmas drew me into new territories, including the nature of rumor, folk wisdom, and conspiratorial thinking; the contrast between rationality within an individual and in a community; and the distinction between two modes of believing: the reality mindset and the mythology mindset.

Finally, though it may seem paradoxical to lay out rational arguments for rationality itself, it's a timely assignment. Some people pursue the opposite paradox, citing reasons (presumably rational ones, or why should we listen?) that rationality is overrated, such as that logical personalities are joyless and repressed, analytical thinking must be subordinated to social justice, and a good heart and reliable gut are surer routes to well-being than tough-minded logic and argument. Many act as if rationality is obsolete—as if the point of argumentation is to discredit one's adversaries rather than collectively reason our way to the most defensible beliefs. In an era in which rationality seems both more threatened and more essential than ever, *Rationality* is, above all, an affirmation of rationality.

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A MAJOR THEME of this book is that none of us, thinking alone, is rational enough to consistently come to sound conclusions: rationality emerges from a community of reasoners who spot each other's fallacies. In that spirit I thank the reasoners who made this book more rational. Ken Binmore, Rebecca Newberger Goldstein, Gary King, Jason Nemirow, Roslyn Pinker, Keith Stanovich, and Martina Wiese incisively commented on the first draft. Charleen Adams, Robert Aumann, Joshua Hartshorne, Louis Liebenberg, Colin McGinn, Barbara Mellers, Hugo Mercier, Judea Pearl, David Ropeik, Michael Shermer, Susanna Siegel, Barbara Spellman, Lawrence Summers, Philip Tetlock, and Juliani Vidal reviewed chapters in their areas of expertise. Many questions arose as I planned and wrote the book, and they were answered by Daniel Dennett, Emily-Rose Eastop, Baruch Fischhoff, Reid Hastie, Nathan Kuncel, Ellen Langer, Jennifer Lerner, Beau Lotto, Daniel Loxton, Gary Marcus, Philip Maymin, Don Moore, David Myers, Robert Proctor, Fred Shapiro, Mattie Toma, Jeffrey Watumull, Jeremy Wolfe, and Steven Zipperstein. I counted on the expert transcription, fact-checking, and reference hunting by Mila Bertolo, Martina Wiese, and Kai Sandbrink, and on original data analyses by Bertolo, Toma, and Julian De Freitas. Also appreciated were the questions and suggestions from the students and teaching staff of General Education 1066: Rationality, especially Mattie Toma and Jason Nemirow.

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1
HOW RATIONAL AN ANIMAL?

> Man is a rational animal. So at least we have been told. Throughout a long life I have searched diligently for evidence in favor of this statement. So far, I have not had the good fortune to come across it.
>
> —Bertrand Russell[1]

> He that can carp in the most eloquent or acute manner at the weakness of the human mind is held by his fellows as almost divine.
>
> —Baruch Spinoza[2]

Homo sapiens means wise hominin, and in many ways we have earned the specific epithet of our Linnaean binomial. Our species has dated the origin of the universe, plumbed the nature of matter and energy, decoded the secrets of life, unraveled the circuitry of consciousness, and chronicled our history and diversity. We have applied this knowledge to enhance our own flourishing, blunting the scourges that immiserated our ancestors for most of our existence. We have postponed our expected date with death from thirty years of age to more than seventy (eighty in developed countries), reduced extreme poverty from ninety percent of humanity to less than nine, slashed the rates of death from war twentyfold and from famine a hundredfold.[3] Even when the ancient bane of pestilence rose up anew in the twenty-first century, we identified the cause within days, sequenced its genome within weeks, and administered vaccines within a year, keeping its death toll to a fraction of those of historic pandemics.

The cognitive wherewithal to understand the world and bend it to our advantage is not a trophy of Western civilization; it's the patrimony of our species. The San of the Kalahari Desert in southern Africa are one of the world's oldest peoples, and their foraging lifestyle, maintained until recently, offers a glimpse of the ways in which humans spent most of their existence.[4] Hunter-gatherers don't just chuck spears at passing animals or help themselves to fruit and nuts growing around them.[5] The tracking scientist Louis Liebenberg, who has worked with the San for decades, has described how they owe their survival to a scientific mindset.[6] They reason their way from fragmentary data to remote conclusions with an intuitive grasp of logic, critical thinking, statistical reasoning, causal inference, and game theory.

The San engage in persistence hunting, which puts to use our three most conspicuous traits: our two-leggedness, which enables us to run efficiently; our hairlessness, which enables us to dump heat in hot climates; and our big heads, which enable us to be rational. The San deploy this rationality to track the fleeing animals from their hoofprints, effluvia, and other spoor, pursuing them until they keel over from exhaustion and heat stroke.[7] Sometimes the San track an animal along one of its habitual pathways, or, when a trail goes cold, by searching in widening circles around the last known prints. But often they track them by reasoning.

Hunters distinguish dozens of species by the shapes and spacing of their tracks, aided by their grasp of cause and effect. They may infer that a deeply pointed track comes from an agile springbok, which needs a good grip, whereas a flat-footed track comes from a heavy kudu, which has to support its weight. They can sex the animals from the configuration of their tracks and the relative location of their urine to their hind feet and droppings. They use these categories to make syllogistic deductions: steenbok and duiker can be run down in the rainy season because the wet sand forces open their hooves and stiffens their joints; kudu and eland can be run down in the dry season because they tire easily in loose sand. It's the dry season and the animal that left these tracks is a kudu; therefore, this animal can be run down.

The San don't just pigeonhole animals into categories but make finer-grained logical distinctions. They tell individuals apart within a species by reading their hoofprints, looking for telltale nicks and variations. And they distinguish an individual's permanent traits, like its species and sex, from transient conditions like fatigue, which they infer from signs of hoof-dragging and stopping to rest. Defying the canard that premodern peoples have no concept of time, they estimate the age of an animal from the size and crispness of its hoofprints, and can date its spoor by the freshness of tracks, the wetness of saliva or droppings, the angle of the sun relative to a shady resting place, and the palimpsest of superimposed tracks from other animals. Persistence hunting could not succeed without those logical niceties. A hunter can't track just any gemsbok from among the many that have left tracks, but only the one he has been pursuing to exhaustion.

The San also engage in critical thinking. They know not to trust their first impressions, and appreciate the dangers of seeing what they want to see. Nor will they accept arguments from authority: anyone, including a young upstart, may shoot down a conjecture or come up with his own until a consensus emerges from the disputation. Though it's mainly the men who hunt, the women are just as knowledgeable at interpreting spoor, and Liebenberg reports that one young woman, !Nasi, "put the men to shame."[8]

The San adjust their credence in a hypothesis according to how diagnostic the evidence is, a matter of conditional probability. A porcupine foot, for instance, has two proximal pads while a honey badger has one, but a padprint may fail to register on hard ground. This means that though the probability that a track will have one padprint given that it was made by a honey badger is high, the inverse probability, that a track was made by a honey badger given that it has one padprint, is lower (since it could also be an incomplete porcupine track). The San do not confuse these conditional probabilities: they know that since two padprints could only have been left by a porcupine, the probability of a porcupine given two padprints is high.

The San also calibrate their credence in a hypothesis according to its prior plausibility. If tracks are ambiguous, they will assume they come from a commonly occurring species; only if the evidence is definitive will they conclude that they come from a rarer one.[9] As we shall see, this is the essence of Bayesian reasoning.

Another critical faculty exercised by the San is distinguishing causation from correlation. Liebenberg recalls: "One tracker, Boroh//xao, told me that when the [lark] sings, it dries out the soil, making the roots good to eat. Afterwards, !Nate and /Uase told me that Boroh//xao was wrong—it is not the *bird* that dries out the soil, it is the *sun* that dries out the soil. The bird is only *telling* them that the soil will dry out in the coming months and that it is the time of the year when the roots are good to eat."[10]

The San use their knowledge of the causal texture of their environment not just to understand how it is but to imagine how it might be. By playing out scenarios in their mind's eye, they can think several steps ahead of the animals in their world and devise intricate snares to trap them. One end of a springy branch is anchored in the ground and the stick is bent in half; the other is tied to a noose camouflaged with twigs and sand and held in place by a trigger. They place the snares at the openings of barriers they have built around an antelope's resting place, and guide the animal into the deadly spot with a hurdle the antelope must clear. Or they lure an ostrich to a snare by spotting its tracks under a camelthorn tree (whose pods are an ostrich delicacy) and leaving a conspicuous bone that's too big for the ostrich to swallow, which draws its attention to a smaller but still unswallowable bone, which leads to a still smaller bone, the bait in the snare.

Yet for all the deadly effectiveness of the San's technology, they have survived in an unforgiving desert for more than a hundred thousand years without exterminating the animals they depend on. During a drought, they think ahead to what would happen if they killed the last plant or animal of its kind, and they spare the members of the threatened species.[11] They tailor their conservation plans to the different vulnerabilities of plants, which cannot migrate but recover quickly when the rains return, and animals, which can survive a drought but build back their numbers slowly. And they enforce these conservation efforts against the constant temptation of poaching (everyone feeling they should exploit the scarce species, because if they don't, everyone else will) with an extension of the norms of reciprocity and collective well-being that govern all their resources. It is unthinkable for a San hunter not to share meat with an empty-handed bandmate, or to exclude a neighboring band driven from their drought-stricken territory, since they know that memories are long and some day fortunes may reverse.

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THE SAPIENCE OF THE SAN makes the puzzle of human rationality acute. Despite our ancient capacity for reason, today we are flooded with reminders of the fallacies and follies of our fellows. People gamble and play the lottery, where they are guaranteed to lose, and fail to invest for their retirement, where they are guaranteed to win. Three quarters of Americans believe in at least one phenomenon that defies the laws of science, including psychic

healing (55 percent), extrasensory perception (41 percent), haunted houses (37 percent), and ghosts (32 percent)—which also means that some people believe in houses haunted by ghosts without believing in ghosts.[12] In social media, fake news (such as JOE BIDEN CALLS TRUMP SUPPORTERS "DREGS OF SOCIETY" and FLORIDA MAN ARRESTED FOR TRANQUILIZING AND RAPING ALLIGATORS IN THE EVERGLADES) is diffused farther and faster than the truth, and humans are more likely to spread it than bots.[13]

It has become commonplace to conclude that humans are simply irrational—more Homer Simpson than Mr. Spock, more Alfred E. Neuman than John von Neumann. And, the cynics continue, what else would you expect from descendants of hunter-gatherers whose minds were selected to avoid becoming lunch for leopards? But evolutionary psychologists, mindful of the ingenuity of foraging peoples, insist that humans evolved to occupy the "cognitive niche": the ability to outsmart nature with language, sociality, and know-how.[14] If contemporary humans seem irrational, don't blame the hunter-gatherers.

How, then, can we understand this thing called rationality which would appear to be our birthright yet is so frequently and flagrantly flouted? The starting point is to appreciate that rationality is not a power that an agent either has or doesn't have, like Superman's X-ray vision. It is a kit of cognitive tools that can attain particular goals in particular worlds. To understand what rationality is, why it seems scarce, and why it matters, we must begin with the ground truths of rationality itself: the ways an intelligent agent *ought* to reason, given its goals and the world in which it lives. These "normative" models come from logic, philosophy, mathematics, and artificial intelligence, and they are our best understanding of the "correct" solution to a problem and how to find it. They serve as an aspiration for those who want to be rational, which should mean everyone. A major goal of this book is to explain the most widely applicable normative tools of reason; they are the subjects of chapters 3 to 9.

Normative models also serve as benchmarks against which we can assess how human schlemiels *do* reason, the subject matter of psychology and the other behavioral sciences. The many ways in which ordinary people fall short of these benchmarks have become famous through the Nobel Prize–winning research of Daniel Kahneman, Amos Tversky, and other psychologists and behavioral economists.[15] When people's judgments deviate from a normative model, as they so often do, we have a puzzle to solve. Sometimes the disparity reveals a genuine irrationality: the human brain cannot cope with the complexity of a problem, or it is saddled with a bug that cussedly drives it to the wrong answer time and again.

But in many cases there is a method to people's madness. A problem may have been presented to them in a deceptive format, and when it is translated into a mind-friendlier guise, they solve it. Or the normative model may itself be correct only in a particular environment, and people accurately sense that they are not in that one, so the model doesn't apply. Or the model may be designed to bring about a certain goal, and, for better or worse, people are after a different one. In the chapters to come, we will see examples of all these extenuating circumstances. The penultimate chapter will lay out how some of today's florid outbursts of irrationality may be understood as the rational pursuit of goals other than an objective understanding of the world.

Though explanations of irrationality may absolve people of the charge of outright stupidity, to understand is not to forgive. Sometimes we can hold people to a higher standard. They can be taught to spot a deep problem across its superficial guises. They can be goaded into applying their best habits of thinking outside their comfort zones. And they can be inspired to set their sights higher than self-defeating or collectively destructive goals. These, too, are aspirations of the book.

Since a recurring insight of the study of judgment and decision making is that humans become more rational when the information they're dealing with is more vivid and relevant, let me turn to examples. Each of these classics—from math, logic, probability, and forecasting—exposes a quirk in our reasoning and will serve as a preview of the normative standards of rationality (and the ways in which people depart from them) in the chapters to come.

Three Simple Math Problems

Everyone remembers being tormented in high school by algebra problems about where the train that left Eastford traveling west at 70 miles per hour will meet the train that left Westford, 260 miles away, traveling east at 60 miles per hour. These three are simpler; you can do them in your head:

- A smartphone and a case cost $110 in total. The phone costs $100 more than the case. How much does the case cost?

- It takes 8 printers 8 minutes to print 8 brochures. How long would it take 24 printers to print 24 brochures?
- On a field there is a patch of weeds. Every day the patch doubles in size. It takes 30 days for the patch to cover the whole field. How long did it take for the patch to cover half the field?

The answer to the first problem is $5. If you're like most people, you guessed $10. But if that were right, the phone would cost $110 ($100 more than the case), and the total for the pair would be $120.

The answer to the second question is 8 minutes. It takes a printer 8 minutes to print a brochure, so as long as there are as many printers as there are brochures and they are working simultaneously, the time it takes to print the brochures is the same.

The answer to the third problem is 29 days. If the weed patch doubles every day, then by working backwards from when the field was completely covered, we may infer that it was half covered the day before.

The economist Shane Frederick gave these questions (with different examples) to thousands of university students. Five out of six got at least one of them wrong; one in three got them *all* wrong.[16] Yet each question has a simple answer that almost everyone understands when it's pointed out. The problem is that people's heads are turned by superficial features of the problem which they mistakenly think are relevant to the answer, such as the round numbers 100 and 10 in the first problem and the fact that the number of printers is the same as the number of minutes in the second.

Frederick calls his low-tech battery the Cognitive Reflection Test, and suggests that it exposes a cleavage between two cognitive systems, later made famous by Kahneman (his sometime coauthor) in the 2011 bestseller *Thinking, Fast and Slow.* System 1 operates rapidly and effortlessly, and it seduces us with the wrong answers; System 2 requires concentration, motivation, and the application of learned rules, and it allows us to grasp the right ones. No one thinks these are literally two anatomical systems in the brain; they are two modes of operation which cut across many brain structures. System 1 means snap judgments; System 2 means thinking twice.

The lesson of the Cognitive Reflection Test is that blunders of reasoning may come from thoughtlessness rather than ineptitude.[17] Even students at the math-proud Massachusetts Institute of Technology averaged only two out of three correct. Performance does correlate with math skill, as you'd expect, but it also correlates with patience. People who describe themselves as not impulsive, and who would rather wait for a larger payment in a month than get a smaller one right away, are less likely to fall into the traps.[18]

The first two items feel like trick questions. That is because they give details which, in the back-and-forth of conversation, would be relevant to what the speaker is asking, but in these examples are designed to lead the hearer astray. (People do better when the smartphone costs, say, $73 more than the case and the combination costs $89.)[19] But of course real life is also baited with garden paths and siren songs that lure us from good decisions, and resisting them is a part of being rational. People who fall for the alluring but wrong answers on the Cognitive Reflection Test appear to be less rational in other ways, such as turning down lucrative offers that require a bit of waiting or a bit of risk.

And the third problem, the one with the weed patch, is not a trick question but taps a real cognitive infirmity. Human intuition doesn't grasp exponential (geometric) growth, namely something that rises at a rising rate, proportional to how large it already is, such as compound interest, economic growth, and the spread of a contagious disease.[20] People mistake it for steady creep or slight acceleration, and their imaginations don't keep up with the relentless doubling. If you deposit $400 a month into a retirement account that earns 10 percent annually, how big will your nest egg be after forty years? Many people guess around $200,000, which is what you get by multiplying 400 by 12 by 110% by 40. Some know that that can't be right and adjust their guess upward, but never enough. Almost no one gets the correct answer: $2.5 *million*. People with a shaky grasp of exponential growth have been found to save less for retirement and to take on more credit-card debt, two roads to penury.[21]

A failure to visualize exponential blastoff can trap experts as well—even experts in cognitive biases. When Covid-19 arrived in the United States and Europe in February 2020, several social scientists (including two heroes of this book, though not Kahneman himself) opined that people were irrationally panicking because they had read about a gruesome case or two and got carried away by the "availability bias" and "probability neglect." The objective risk at the time, they noted, was lower than that of the flu or strep throat, which everyone accepts calmly.[22] The fallacy of the fallacy scolds was to underestimate the accelerating rate at which a disease as contagious as Covid can spread, with each patient not only infecting new ones but turning each of them into an infector. The single confirmed American death on March 1 grew in successive weeks to 2, 6, 40, 264, 901, and 1,729 deaths per day, adding up to more than 100,000 deaths by June 1 and soon making it the most lethal hazard in the country.[23] Of course the authors of these obscure op-eds cannot be blamed for the insouciance which lulled

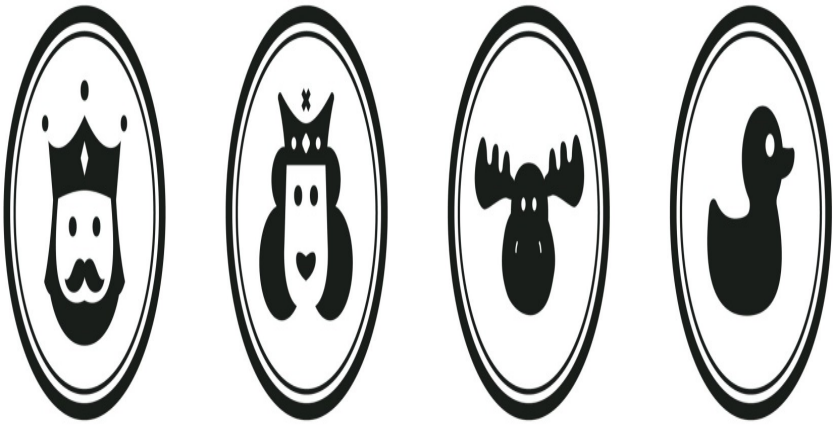
so many leaders and citizens into dangerous complacency, but their comments show how deeply rooted cognitive biases can be.

Why do people misunderestimate exponential growth, as George W. Bush might have put it? In the great tradition of the physician in the Molière play who explained that opium makes people sleepy because of its dormitive power, social scientists attribute the errors to an "exponential growth bias." Less circularly, we might point to the ephemerality of exponential processes in natural environments (prior to historical innovations like economic growth and compound interest). Things that can't go on forever don't, and organisms can multiply only to the point where they deplete, foul, or saturate their environments, bending the exponential curve into an S. This includes pandemics, which peter out once enough susceptible hosts in the herd are killed or develop immunity.

A Simple Logic Problem

If anything lies at the core of rationality, it must surely be logic. The prototype of a rational inference is the syllogism "If P then Q. P. Therefore, Q." Consider a simple example.

Suppose the coinage of a country has a portrait of one of its eminent sovereigns on one side and a specimen of its magnificent fauna on the other. Now consider a simple if-then rule: "If a coin has a king on one side, then it has a bird on the other." Here are four coins, displaying a king, a queen, a moose, and a duck. Which of the coins do you have to turn over to determine whether the rule has been violated?



If you're like most people, you said "the king" or "the king and the duck." The correct answer is "the king and the moose." Why? Everyone agrees you have to turn over the king, because if you failed to find a bird on the reverse it would violate the rule in so many words. Most people know there's no point in turning over the queen, because the rule says "If king, then bird"; it says nothing about coins with a queen. Many say you should turn over the duck, but when you think about it, that coin is irrelevant. The rule is "If king, then bird," not "If bird, then king": if the duck shared the coin with a queen, nothing would be amiss. But now consider the moose. If you turned that coin over and found a king on the obverse, the rule "If king, then bird" would have been transgressed. The answer, then, is "the king and the moose." On average, only 10 percent of people make those picks.

The Wason selection task (named after its creator, the cognitive psychologist Peter Wason) has been administered with various "If P then Q" rules for sixty-five years. (The original version used cards with a letter on one side and a number on the other and a rule like "If there is a D on one side, there is a 3 on the other.") Time and again people turn over the P, or the P and the Q, and fail to turn over the not-Q.[24] It's not that they're incapable of understanding the right answer. As with the Cognitive Reflection Test, as soon as it is explained to them they slap themselves on the forehead and accept it.[25] But their unreflective intuition, left to its own devices, fails to do the logic.

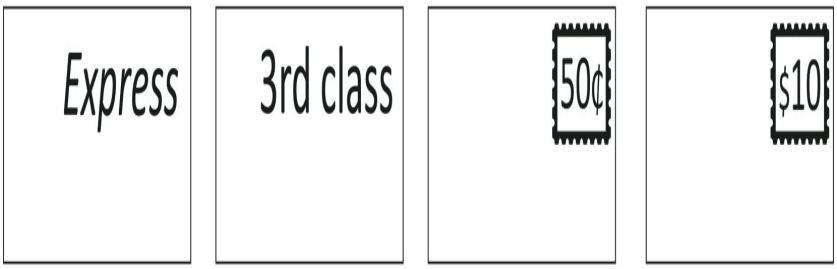
What does this tell us about human rationality? A common explanation is that it reveals our *confirmation bias*: the bad habit of seeking evidence that ratifies a belief and being incurious about evidence that might falsify it.[26] People think that dreams are omens because they recall the time when they dreamt a relative had a mishap and she did, but they forget about all the times when a relative was fine after they dreamt she had a mishap. Or they think

immigrants commit a lot of crime because they read in the news about an immigrant who robbed a store, but don't think about the larger number of stores robbed by native-born citizens.

Confirmation bias is a common diagnosis for human folly and a target for enhancing rationality. Francis Bacon (1561–1626), often credited with developing the scientific method, wrote of a man who was taken to a church and shown a painting of sailors who had escaped a shipwreck thanks to their holy vows. "Aye," he remarked, "but where are they painted that were drowned after their vows?"[27] He observed, "Such is the way of all superstitions, whether in astrology, dreams, omens, divine judgments, or the like; wherein men, having a delight in such vanities, mark the events where they are fulfilled, but where they fail, although this happened much oftener, neglect and pass them by."[28] Echoing a famous argument by the philosopher Karl Popper, most scientists today insist that the dividing line between science and pseudoscience is whether advocates of a hypothesis deliberately search for evidence that could falsify it and accept the hypothesis only if it survives.[29]

How can humans make it through the day with an inability to apply the most elementary rule of logic? Part of the answer is that the selection task is a peculiar challenge.[30] It doesn't ask people to apply the syllogism to make a useful deduction ("Here's a coin with a king; what's on the other side?") or to test the rule in general ("Is the rule true of the country's coinage?"). It asks whether the rule applies specifically to each of a handful of items before them on the table. The other part of the answer is that people do apply logic when the rule involves the shoulds and shouldn'ts of human life rather than arbitrary symbols and tokens.

Suppose the Post Office sells fifty-cent stamps for third-class mail but requires ten-dollar stamps for Express Mail. That is, properly addressed mail must follow the rule "If a letter is labeled Express Mail, it must have a ten-dollar stamp." Suppose the label and the stamp don't fit on the same side of the envelope, so a postal worker has to turn envelopes over to check to see if the sender has followed the rule. Here are four envelopes. Imagine that you are a postal worker. Which ones do you have to turn over?



The correct answer once again is P and not-Q, namely the Express envelope and the one with the fifty-cent stamp. Though the problem is logically equivalent to the four-coin problem, this time almost everyone gets it right. The content of a logical problem matters.[31] When an if-then rule implements a contract involving permissions and duties—"If you enjoy a benefit, you must pay a cost"—then a violation of the rule (take the benefit, don't pay the cost) is equivalent to cheating, and people intuitively know what it takes to catch a cheater. They don't check up on people who aren't enjoying the benefit or people who have paid a cost, neither of whom could be trying to get away with something.

Cognitive psychologists debate exactly what kinds of content temporarily turn people into logicians. They can't be just any concrete scenarios, but must embody the kinds of logical challenges that we became attuned to as we developed into adults and perhaps when we evolved into humans. Monitoring a privilege or duty is one of these logic-unlocking themes; monitoring danger is another. People know that to verify compliance with the precaution "If you ride a bicycle, then you must wear a helmet," they have to check that a child on a bicycle is wearing a helmet and that a child without a helmet does not get onto a bicycle.

Now, a mind that can falsify a conditional rule when the violations are tantamount to cheating or danger is not exactly a logical mind. Logic, by definition, is about the form of statements, not their content: how Ps and Qs are connected by IF, THEN, AND, OR, NOT, SOME, and ALL, regardless of what the Ps and Qs stand for. Logic is a crowning achievement of human knowledge. It organizes our reasoning with unfamiliar or abstract subject matter, such as the laws of government and science, and when implemented in silicon it turns inert matter into thinking machines. But what the untutored human mind commands is not a general-purpose, content-free tool, with formulas like "[IF P THEN Q] is equivalent to NOT-[P AND NOT Q]," into which any P and Q can be plugged. It commands a set of more specialized tools that bake together the content relevant to the problem with the rules of logic (without those rules, the tools wouldn't work). It isn't easy for people to extricate the rules and wield them in novel, abstract, or apparently meaningless problems. That's what education and other rationality-enhancing institutions are for. They

augment the *ecological rationality* we are born and grow up with—our horse sense, our street smarts—with the broader-spectrum and more potent tools of reasoning perfected by our best thinkers over the millennia.[32]

A Simple Probability Problem

One of the most famous television game shows from the heyday of the genre from the 1950s to the 1980s was *Let's Make a Deal*. Its host, Monty Hall, achieved a second kind of fame when a dilemma in probability theory, loosely based on the show, was named after him.[33] A contestant is faced with three doors. Behind one of them is a sleek new car. Behind the other two are goats. The contestant picks a door, say Door 1. To build suspense, Monty opens one of the other two doors, say Door 3, revealing a goat. To build the suspense still further, he gives the contestant an opportunity either to stick with their original choice or to switch to the unopened door. You are the contestant. What should you do?

Almost everyone stays.[34] They figure that since the car was placed behind one of the three doors at random, and Door 3 has been eliminated, there is now a fifty-fifty chance each that the car will be behind Door 1 or Door 2. Though there's no harm in switching, they think, there's no benefit either. So they stick with their first choice out of inertia, pride, or anticipation that their regret after an unlucky switch would be more intense than their delight after a lucky one.

The Monty Hall dilemma became famous in 1990 when it was presented in the "Ask Marilyn" column in *Parade*, a magazine inserted in the Sunday edition of hundreds of American newspapers.[35] The columnist was Marilyn vos Savant, known at the time as "the world's smartest woman" because of her entry in the *Guinness Book of World Records* for the highest score on an intelligence test. Vos Savant wrote that you should switch: the odds of the car being behind Door 2 are two in three, compared with one in three for Door 1. The column drew ten thousand letters, a thousand of them from PhDs, mainly in mathematics and statistics, most of whom said she was wrong. Here are some examples:

> You blew it, and you blew it big! Since you seem to have difficulty grasping the basic principle at work here, I'll explain. After the host reveals a goat, you now have a one-in-two chance of being correct. Whether you change your selection or not, the odds are the same. There is enough mathematical illiteracy in this country, and we don't need the world's highest IQ propagating more. Shame!
>
> —Scott Smith, PhD, University of Florida

> I am sure you will receive many letters on this topic from high school and college students. Perhaps you should keep a few addresses for help with future columns.
>
> —W. Robert Smith, PhD, Georgia State University

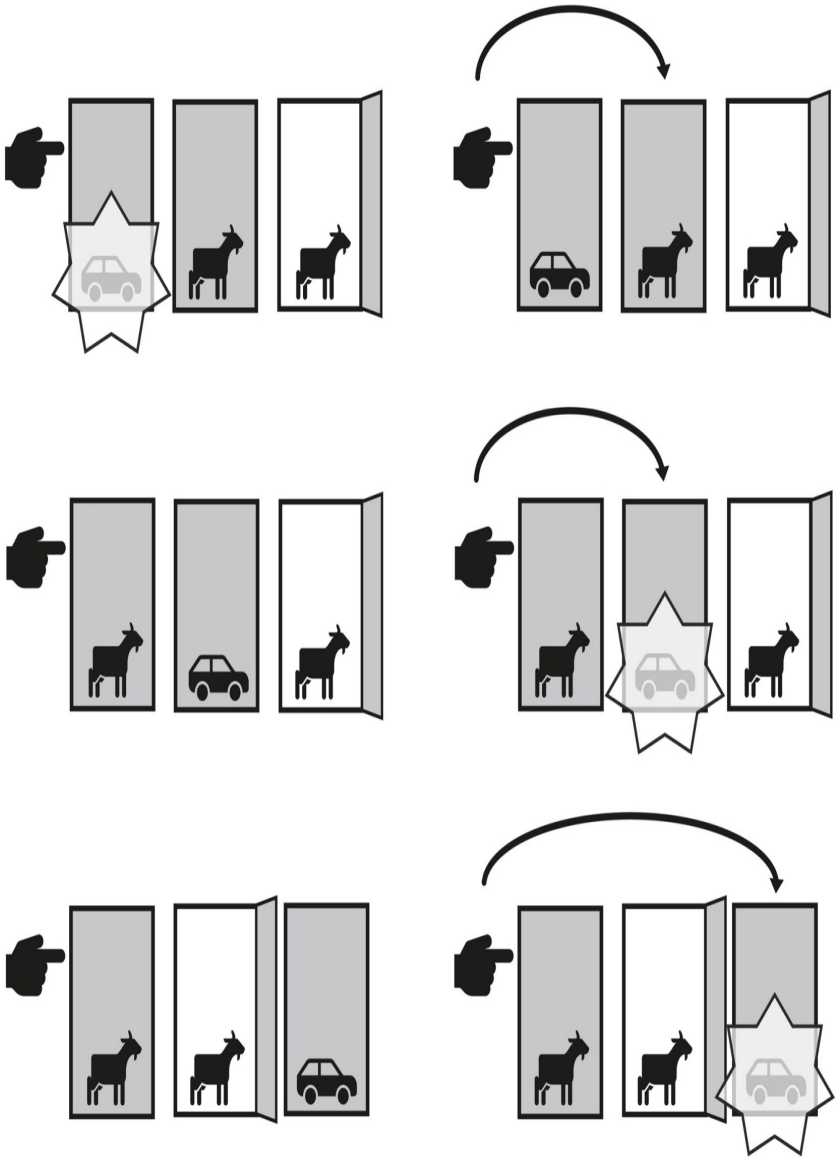
> Maybe women look at math problems differently than men.
>
> —Don Edwards, Sunriver, Oregon[36]

Among the objectors was Paul Erdös (1913–1996), the renowned mathematician who was so prolific that many academics boast of their "Erdös number," the length of the shortest chain of coauthorships linking them to the great theoretician.[37]

But the mansplaining mathematicians were wrong and the world's smartest woman was right. You should switch. It's not that hard to see why. There are three possibilities for where the car could have been placed. Let's consider each door and count up the number of times out of the three that you would win with each strategy. You picked Door 1, but of course that's just a label; as long as Monty follows the rule "Open an unselected door with a goat; if both have goats, pick one at random," the odds come out the same whichever door you picked.

Suppose your strategy is "Stay" (left column in the figure). If the car is behind Door 1 (top left), you win. (It doesn't matter which of the other doors Monty opened, because you're not switching to either.) If the car is behind Door 2 (middle left), you lose. If the car is behind Door 3 (bottom left), you lose. So the odds of winning with the "Stay" strategy are one in three.

Now suppose your strategy is “Switch” (right column). If the car is behind Door 1, you lose. If the car is behind Door 2, Monty would have opened Door 3, so you would switch to Door 2 and win. If the car is behind Door 3, he would have opened Door 2, so you would switch to Door 3 and win. The odds of winning with the “Switch” strategy are two in three, double the odds of staying.



It’s not rocket surgery.[38] Even if you don’t work through the logical possibilities, you could play a few rounds yourself with cutouts and toys and tot up the outcomes, as Hall himself did to convince a skeptical journalist. (Nowadays, you can play it online.)[39] Or you could pursue the intuition “Monty knows the answer and gave me a clue; it would be foolish not to act on it.” Why did the mathematicians, professors, and other bigshots get it so wrong?

Certainly there were failures of critical thinking coming from sexism, ad hominem biases, and professional jealousy. Vos Savant is an attractive and stylish woman with no initials after her name who wrote for a recipe- and gossip-filled rag and bantered on late-night talk shows.[40] She defied the stereotype of a mathematician, and her celebrity and bragging rights from *Guinness* made her a big fat target for a takedown.

But part of the problem is the problem itself. Like the teasers in the Cognitive Reflection and Wason selection tests, something about the Monty Hall dilemma is designed to bring out the stupid in our System 1. But in this case System 2 is not much brighter. Many people can’t swallow the correct explanation even when it’s pointed out to

them. This included Erdös, who, violating the soul of a mathematician, was convinced only when he saw the game repeatedly simulated.[41] Many persist even when they see it simulated and even when they repeatedly play for money. What's the mismatch between our intuitions and the laws of chance?

A clue comes from the overconfident justifications that the know-it-alls offered for their blunders, sometimes thoughtlessly carried over from other probability puzzles. Many people insist that each of the unknown alternatives (in this case, the unopened doors) must have an equal probability. That is true of symmetrical gambling toys like the faces of a coin or sides of a die, and it is a reasonable starting point when you know absolutely nothing about the alternatives. But it is not a law of nature.

Many visualize the causal chain. The car and goats were placed prior to the reveal, and opening a door can't move them around after the fact. Pointing out the independence of causal mechanisms is a common way to debunk other illusions such as the gambler's fallacy, in which people misguidedly think that after a run of reds the next spin of the roulette wheel will turn up black, when in fact the wheel has no memory, so every spin is independent. As one of vos Savant's correspondents mansplained, "Picture a race with three horses, each having an equal chance of winning. If horse #3 drops dead 50 feet into the race, the chances for each of the remaining two horses are no longer one in three but rather are now one in two." Clearly, he concluded, it would not make sense to switch one's bet from horse #1 to horse #2. But this is not how the problem works. Imagine that after you place your bet on #1, God announces, "It's not going to be horse #3." He could have warned against horse #2 but didn't. Switching your bet doesn't sound so crazy.[42] In *Let's Make a Deal*, Monty Hall is God.

The godlike host reminds us how exotic the Monty Hall problem is. It requires an omniscient being who defies the usual goal of a conversation—to share what the hearer needs to know (in this case, which door hides the car)—and instead pursues the goal of enhancing suspense among third parties.[43] And unlike the world, whose clues are indifferent to our sleuthing, Monty Almighty knows the truth and knows our choice and picks his revelation accordingly.

People's insensitivity to this lucrative but esoteric information pinpoints the cognitive weakness at the heart of the puzzle: we confuse *probability* with *propensity.* A propensity is the disposition of an object to act in certain ways. Intuitions about propensities are a major part of our mental models of the world. People sense that bent branches tend to spring back, that kudu may tire easily, that porcupines usually leave tracks with two padprints. A propensity cannot be perceived directly (either the branch sprang back or it didn't), but it can be inferred by scrutinizing the physical makeup of an object and working through the laws of cause and effect. A drier branch may snap, a kudu has more stamina in the rainy season, a porcupine has two proximal pads which leave padprints when the ground is soft but not necessarily when it is hard.

But probability is different; it is a conceptual tool invented in the seventeenth century.[44] The word has several meanings, but the one that matters in making risky decisions is the strength of one's belief in an unknown state of affairs. Any scrap of evidence that alters our confidence in an outcome will change its probability and the rational way to act upon it. The dependence of probability on ethereal knowledge rather than just physical makeup helps explain why people fail at the dilemma. They intuit the propensities for the car to have ended up behind the different doors, and they know that opening a door could not have changed those propensities. But probabilities are not about the world; they're about our *ignorance* of the world. New information reduces our ignorance and changes the probability. If that sounds mystical or paradoxical, think about the probability that a coin I just flipped landed heads. For you, it's .5. For me, it's 1 (I peeked). Same event, different knowledge, different probability. In the Monty Hall dilemma, new information is provided by the all-seeing host.

One implication is that when the reduction of ignorance granted by the host is more transparently connected to the physical circumstances, the solution to the problem becomes intuitive. Vos Savant invited her readers to imagine a variation of the game show with, say, a thousand doors.[45] You pick one. Monty reveals a goat behind 998 of the others. Would you switch to the door he left closed? This time it seems clear that Monty's choice conveys actionable information. One can visualize him scanning the doors for the car as he decides which one not to open, and the closed door is a sign of his having spotted the car and hence a spoor of the car itself.

A Simple Forecasting Problem

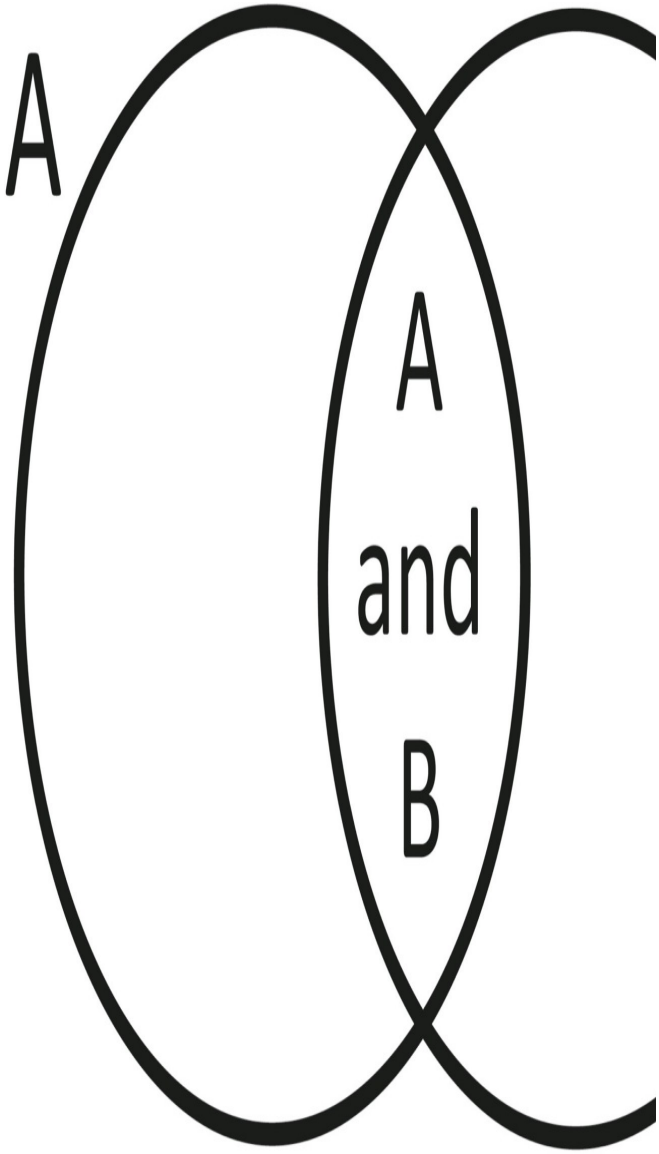
Once we get into the habit of assigning numbers to unknown events, we can quantify our intuitions about the future. Forecasting events is big business. It informs policy, investment, risk management, and ordinary curiosity about what lies in store for the world. Consider each of the following events, and write down your estimate of the likelihood that it will take place in the coming decade. Many of them are pretty unlikely, so let's make finer

distinctions at the lower end of the scale and pick one of the following probabilities for each: less than .01 percent, .1 percent, .5 percent, 1 percent, 2 percent, 5 percent, 10 percent, 25 percent, and 50 percent or more.

1. Saudi Arabia develops a nuclear weapon.
2. Nicolás Maduro resigns as president of Venezuela.
3. Russia has a female president.
4. The world suffers a new and even more lethal pandemic than Covid-19.
5. Vladimir Putin is constitutionally prevented from running for another term as president of Russia and his wife takes his place on the ballot, allowing him to run the country from the sidelines.
6. Massive strikes and riots force Nicolás Maduro to resign as president of Venezuela.
7. A respiratory virus jumps from bats to humans in China and starts a new and even more lethal pandemic than Covid-19.
8. After Iran develops a nuclear weapon and tests it in an underground explosion, Saudi Arabia develops its own nuclear weapon in response.

I presented items like these to several hundred respondents in a survey. On average, people thought it was likelier that Putin's wife would be president of Russia than that a woman would be president. They thought it was likelier that strikes would force Maduro to resign than that he would resign. They thought Saudi Arabia was more likely to develop a nuclear weapon in response to an Iranian bomb than it was to develop a nuclear weapon. And they thought it was likelier that Chinese bats would start a pandemic than that there would be a pandemic.[46]

You probably agree with at least one of these comparisons; 86 percent of the participants who rated all the items did. If so, you violated an elementary law of probability, the conjunction rule: the probability of a conjunction of events (A and B) must be less than or equal to the probability of either of the events (A, or B). The probability of picking an even-numbered spade out of a deck of cards, for example (even and spade), has to be less than the probability of picking a spade, because some spades are not even numbers.



In each pair of world events, the second scenario is a conjunction of events, one of which is the event in the first scenario. For example, “Iran tests a nuclear weapon and Saudi Arabia develops a nuclear weapon” is a conjunction that embraces “Saudi Arabia develops a nuclear weapon” and must have a smaller chance of happening, since there are other scenarios in which the Saudis might go nuclear (to counter Israel, to flaunt hegemony over the Persian Gulf, and so on). By the same logic, Maduro resigning the presidency has to be more likely than Maduro resigning the presidency after a series of strikes.