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THE DRUNKARD'S WALK

How Randomness Rules Our Lives

LEONARD MLODINOW

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Leonard Mlodinow

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CONTENTS

To my three miracles of randomness:
Olivia, Nicolai, and Alexei…
and for Sabina Jakubowicz

PROLOGUE

A FEW YEARS AGO a man won the Spanish national lottery with a ticket that ended in the number 4 Proud of his “accomplishment,” he revealed the theory that brought him the riches. “I dreamed of tl number 7 for seven straight nights,” he said, “and 7 times 7 is 48.”[1] Those of us with a bett command of our multiplication tables might chuckle at the man’s error, but we all create our ow view of the world and then employ it to filter and process our perceptions, extracting meaning fro the ocean of data that washes over us in daily life. And we often make errors that, though less obviou are just as significant as his.

The fact that human intuition is ill suited to situations involving uncertainty was known as early the 1930s, when researchers noted that people could neither make up a sequence of numbers th passed mathematical tests for randomness nor recognize reliably whether a given string was random generated. In the past few decades a new academic field has emerged to study how people mal judgments and decisions when faced with imperfect or incomplete information. Their research h shown that when chance is involved, people’s thought processes are often seriously flawed. The wor draws from many disciplines, from mathematics and the traditional sciences as well as cogniti psychology, behavioral economics, and modern neuroscience. But although such studies we legitimated by a recent Nobel Prize (in Economics), their lessons for the most part have not trickl down from academic circles to the popular psyche. This book is an attempt to remedy that. It is abo the principles that govern chance, the development of those ideas, and the manner in which they pla out in politics, business, medicine, economics, sports, leisure, and other areas of human affairs. It also about the way we make choices and the processes that lead us to make mistaken judgments ar poor decisions when confronted with randomness or uncertainty.

Information that is lacking often invites competing interpretations. That’s why such great effort w required to confirm global warming, why drugs are sometimes declared safe and then pulled from tl market, and presumably why not everyone agrees with my observation that chocolate milkshakes a an indispensable component of a heart-healthy diet. Unfortunately the misinterpretation of data h many negative consequences, both large and small. As we’ll see, for example, both doctors ar patients often misinterpret statistics regarding the effectiveness of drugs and the meaning of importa medical tests. Parents, teachers, and students misunderstand the significance of exams such as tl SAT, and wine connoisseurs make the same mistakes about wine ratings. Investors draw invali conclusions from the historical performance of mutual funds.

In sports we have developed a culture in which, based on intuitive feelings of correlation, a team success or failure is often attributed largely to the ability of the coach. As a result, when teams fa the coach is often fired. Mathematical analysis of firings in all major sports, however, has shown th those firings had, on average, no effect on team performance.[2] An analogous phenomenon occurs the corporate world, where CEOs are thought to have superhuman power to make or break a compan

Yet time and time again at Kodak, Lucent, Xerox, and other companies, that power has prove illusory. ~~In the 1990s, for instance, when he ran GE Capital Services under Jack Welch, Gary Wend~~ was thought of as one of the smartest businessmen in the country. Wendt parlayed that reputation int a $45 million bonus when he was hired to run the troubled finance company Conseco. Investo apparently agreed that with Wendt at the helm, Conseco's troubles were over: the company's stoc tripled within a year. But two years after that Wendt abruptly resigned, Conseco went bankrupt, an the stock was trading for pennies.[3] Had Wendt's task been impossible? Was he asleep at the wheel? C had his coronation rested on questionable assumptions—for example, that an executive has a nea absolute ability to affect a company or a person's single past success is a reliable indicator of futu performance? On any specific occasion one cannot be confident of the answers without examining th details of the situation at hand. I will do that in several instances in this book, but more important, will present the tools needed to identify the footprints of chance.

To swim against the current of human intuition is a difficult task. As we'll see, the human mind built to identify for each event a definite cause and can therefore have a hard time accepting th influence of unrelated or random factors. And so the first step is to realize that success or failu sometimes arises neither from great skill nor from great incompetence but from, as the economi Armen Alchian wrote, "fortuitous circumstances."[4] Random processes are fundamental in nature an are ubiquitous in our everyday lives, yet most people do not understand them or think much abo them.

The title *The Drunkard's Walk* comes from a mathematical term describing random motion, such the paths molecules follow as they fly through space, incessantly bumping, and being bumped b their sister molecules. That can be a metaphor for our lives, our paths from college to career, fro single life to family life, from first hole of golf to eighteenth. The surprise is that the tools used understand the drunkard's walk can also be employed to help understand the events of everyday lif The goal of this book is to illustrate the role of chance in the world around us and to show how w may recognize it at work in human affairs. I hope that after this tour of the world of randomness, yo the reader, will begin to see life in a different light, with a deeper understanding of the everyda world.

CHAPTER 1

Peering through the Eyepiece of Randomness

I REMEMBER, as a teenager, watching the yellow flame of the Sabbath candles dancing randomly abov the white paraffin cylinders that fueled them. I was too young to think candlelight romantic, but stil found it magical—because of the flickering images created by the fire. They shifted and morphe grew and waned, all without apparent cause or plan. Surely, I believed, there must be rhyme ar reason underlying the flame, some pattern that scientists could predict and explain with the mathematical equations. “Life isn’t like that,” my father told me. “Sometimes things happen th cannot be foreseen.” He told me of the time when, in Buchenwald, the Nazi concentration camp which he was imprisoned and starving, he stole a loaf of bread from the bakery. The baker had th Gestapo gather everyone who might have committed the crime and line the suspects up. “Who sto the bread?” the baker asked. When no one answered, he told the guards to shoot the suspects one b one until either they were all dead or someone confessed. My father stepped forward to spare th others. He did not try to paint himself in a heroic light but told me that he did it because he expecte to be shot either way. Instead of having him killed, though, the baker gave my father a plum job, as h assistant. “A chance event,” my father said. “It had nothing to do with you, but had it happene differently, you would never have been born.” It struck me then that I have Hitler to thank for m existence, for the Germans had killed my father’s wife and two young children, erasing his prior lif And so were it not for the war, my father would never have emigrated to New York, never have me my mother, also a refugee, and never have produced me and my two brothers.

My father rarely spoke of the war. I didn’t realize it then, but years later it dawned on me th whenever he shared his ordeals, it was not so much because he wanted me to know of his experienc but rather because he wanted to impart a larger lesson about life. War is an extreme circumstance, bu the role of chance in our lives is not predicated on extremes. The outline of our lives, like the candle flame, is continuously coaxed in new directions by a variety of random events that, along with o responses to them, determine our fate. As a result, life is both hard to predict and hard to interpre Just as, looking at a Rorschach blot, you might see Madonna and I, a duck-billed platypus, the data w encounter in business, law, medicine, sports, the media, or your child’s third-grade report card can b read in many ways. Yet interpreting the role of chance in an event is not like intepreting a Rorschac blot; there are right ways and wrong ways to do it.

We often employ intuitive processes when we make assessments and choices in uncertai situations. Those processes no doubt carried an evolutionary advantage when we had to decid whether a saber-toothed tiger was smiling because it was fat and happy or because it was famished ar saw us as its next meal. But the modern world has a different balance, and today those intuitiv processes come with drawbacks. When we use our habitual ways of thinking to deal with today tigers, we can be led to decisions that are less than optimal or even incongruous. That conclusio comes as no surprise to those who study how the brain processes uncertainty: many studies point to close connection between the parts of our brain that make assessments of chance situations and tho that handle the human characteristic that is often considered our prime source of irrationality—o emotions. Functional magnetic resonance imaging, for example, shows that risk and reward a assessed by parts of the dopaminergic system, a brain-reward circuit important for motivational an emotional processes.[1] The images show, too, that the amygdala, which is also linked to our emotion state, especially fear, is activated when we make decisions couched in uncertainty.[2]

The mechanisms by which people analyze situations involving chance are an intricate product evolutionary factors, brain structure, personal experience, knowledge, and emotion. In fact, the huma response to uncertainty is so complex that sometimes different structures within the brain come different conclusions and apparently fight it out to determine which one will dominate. For exampl if your face swells to five times its normal size three out of every four times you eat shrimp, t "logical" left hemisphere of your brain will attempt to find a pattern. The "intuitive" right hemisphe of your brain, on the other hand, will simply say "avoid shrimp." At least that's what researche found in less painful experimental setups. The game is called probability guessing. In lieu of toyi with shrimp and histamine, subjects are shown a series of cards or lights, which can have two colo say green and red. Things are arranged so that the colors will appear with different probabilities b otherwise without a pattern. For example, red might appear twice as often as green in a sequence li red-red-green-red-green-red-red-green-green-red-red-red, and so on. The task of the subject, aft watching for a while, is to predict whether each new member of the sequence will be red or green.

The game has two basic strategies. One is to always guess the color that you notice occurs mo frequently. That is the route favored by rats and other nonhuman animals. If you employ this strateg you are guaranteed a certain degree of success but you are also conceding that you will do no bette For instance, if green shows up 75 percent of the time and you decide to always guess green, you w be correct 75 percent of the time. The other strategy is to "match" your proportion of green and r guesses to the proportion of green and red you observed in the past. If the greens and reds appear in pattern and you can figure out the pattern, this strategy enables you to guess right every time. But the colors appear at random, you would be better off sticking with the first strategy. In the case whe green randomly appears 75 percent of the time, the second strategy will lead to the correct guess on about 6 times in 10.

Humans usually try to guess the pattern, and in the process we allow ourselves to be outperform by a rat. But there are people with certain types of post-surgical brain impairment—called a split bra —that precludes the right and left hemispheres of the brain from communicating with each other. the probability experiment is performed on these patients such that they see the colored light or ca with only their left eye and employ only their left hand to signal their predictions, it amounts to experiment on the right side of the brain. But if the experiment is performed so as to involve on their right eye and right hand, it is an experiment on the left brain. When researchers performed tho experiments, they found that—in the same patients—the right hemisphere always chose to guess t more frequent color and the left hemisphere always tried to guess the pattern.[3]

Making wise assessments and choices in the face of uncertainty is a rare skill. But like any skill, can be improved with experience. In the pages that follow, I will examine the role of chance in t world around us, the ideas that have been developed over the centuries to help us understand that rol and ~~the factors that often lead us astray. The British philosopher and mathematician Bertrand~~ Russe wrote,

> We all start from “naive realism,” i.e., the doctrine that things are what they seem. We think that grass is green, that stones are hard, and that snow is cold. But physics assures us that the greenness of grass, the hardness of stones, and the coldness of snow are not the greenness of grass, the hardness of stones, and the coldness of snow that we know in our own experience, but something very different.[4] In what follows we will peer at life through the eyepiece of randomness and see that many of the events of our lives, too, are not quite what they seem but rather something very different.

In 2002 the Nobel committee awarded the Nobel Prize in Economics to a scientist named Dani Kahneman. Economists do all sorts of things these days—they explain why teachers are paid so littl why football teams are worth so much, and why bodily functions help set a limit on the size of ho farms (a hog excretes three to five times as much as a human, so a farm with thousands of hogs on often produces more waste than the neighboring cities).[5] Despite all the great research generated b economists, the 2002 Nobel Prize was notable because Kahneman is not an economist. He is psychologist, and for decades, with the late Amos Tversky, Kahneman studied and clarified the kind of misperceptions of randomness that fuel many of the common fallacies I will talk about in this boo

The greatest challenge in understanding the role of randomness in life is that although the bas principles of randomness arise from everyday logic, many of the consequences that follow from tho principles prove counterintuitive. Kahneman and Tversky’s studies were themselves spurred by random event. In the mid-1960s, Kahneman, then a junior psychology professor at Hebrew Universit agreed to perform a rather unexciting chore: lecturing to a group of Israeli air force flight instructo on the conventional wisdom of behavior modification and its application to the psychology of flig training. Kahneman drove home the point that rewarding positive behavior works but punishin mistakes does not. One of his students interrupted, voicing an opinion that would lead Kahneman to a epiphany and guide his research for decades.[6]

“I’ve often praised people warmly for beautifully executed maneuvers, and the next time the always do worse,” the flight instructor said. “And I’ve screamed at people for badly execute maneuvers, and by and large the next time they improve. Don’t tell me that reward works an punishment doesn’t work. My experience contradicts it.” The other flight instructors agreed. T Kahneman the flight instructors’ experiences rang true. On the other hand, Kahneman believed in th animal experiments that demonstrated that reward works better than punishment. He ruminated on th apparent paradox. And then it struck him: the screaming preceded the improvement, but contrary t appearances it did not cause it.

How can that be? The answer lies in a phenomenon called regression toward the mean. That is, any series of random events an extraordinary event is most likely to be followed, due purely to chanc by ~~a more ordinary one. Here is how it works: The student pilots all had a certain personal ab~~ility fly fighter planes. Raising their skill level involved many factors and required extensive practice, although their skill was slowly improving through flight training, the change wouldn't be noticeab from one maneuver to the next. Any especially good or especially poor performance was thus mostly matter of luck. So if a pilot made an exceptionally good landing—one far above his normal level performance—then the odds would be good that he would perform closer to his norm—that is, wor —the next day. And if his instructor had praised him, it would appear that the praise had done n good. But if a pilot made an exceptionally bad landing—running the plane off the end of the runwa and into the vat of corn chowder in the base cafeteria—then the odds would be good that the next d he would perform closer to his norm—that is, better. And if his instructor had a habit of screamin "you clumsy ape" when a student performed poorly, it would appear that his criticism did some goo In this way an *apparent* pattern would emerge: student performs well, praise does no good; stude performs poorly, instructor compares student to lower primate at high volume, student improves. Th instructors in Kahneman's class had concluded from such experiences that their screaming was powerful educational tool. In reality it made no difference at all.

This error in intuition spurred Kahneman's thinking. He wondered, are such misconceptio universal? Do we, like the flight instructors, believe that harsh criticism improves our children behavior or our employees' performance? Do we make other misjudgments when faced wi uncertainty? Kahneman knew that human beings, by necessity, employ certain strategies to reduce th complexity of tasks of judgment and that intuition about probabilities plays an important part in th process. Will you feel sick after eating that luscious-looking seviche tostada from the street vendo You don't consciously recall all the comparable food stands you've patronized, count the number times you've spent the following night guzzling Pepto-Bismol, and come up with a numeric estimate. You let your intuition do the work. But research in the 1950s and early '60s indicated th people's intuition about randomness fails them in such situations. How widespread, Kahnema wondered, was this misunderstanding of uncertainty? And what are its implications for huma decision making? A few years passed, and Kahneman invited a fellow junior professor, Amo Tversky, to give a guest lecture at one of his seminars. Later, at lunch, Kahneman mentioned h developing ideas to Tversky. Over the next thirty years, Tversky and Kahneman found that eve among sophisticated subjects, when it came to random processes—whether in military or spor situations, business quandaries, or medical questions—people's beliefs and intuition very often l them down.

Suppose four publishers have rejected the manuscript for your thriller about love, war, and glob warming. Your intuition and the bad feeling in the pit of your stomach might say that the rejections b all those publishing experts mean your manuscript is no good. But is your intuition correct? Is yo novel unsellable? We all know from experience that if several tosses of a coin come up heads, doesn't mean we are tossing a two-headed coin. Could it be that publishing success is so unpredictab that even if our novel is destined for the best-seller list, numerous publishers could miss the point an send those letters that say thanks but no thanks? One book in the 1950s was rejected by publisher who responded with such comments as "very dull," "a dreary record of typical family bickering, pet annoyances and adolescent emotions," and "even if the work had come to light five years ago, wh the subject [World War II] was timely, I don't see that there would have been a chance for it." Th book, *The Diary of a Young Girl* by Anne Frank, has sold 30 million copies, making it one of the bes selling books in history. Rejection letters were also sent to Sylvia Plath because “there certainly isn enough genuine talent for us to take notice,” to George Orwell for *Animal Farm* because “it impossible to sell animal stories in the U.S.,” and to Isaac Bashevis Singer because “it’s Poland an the rich Jews again.” Before he hit it big, Tony Hillerman’s agent dumped him, advising that h should “get rid of all that Indian stuff.”[7]

Those were not isolated misjudgments. In fact, many books destined for great success had survive not just rejection, but repeated rejection. For example, few books today are considered to hav more obvious and nearly universal appeal than the works of John Grisham, Theodor Geisel (D Seuss), and J. K. Rowling. Yet the manuscripts they wrote before they became famous—all eventuall hugely successful—were all repeatedly rejected. John Grisham’s manuscript for *A Time to Kill* w rejected by twenty-six publishers; his second manuscript, for *The Firm*, drew interest from publishe only after a bootleg copy circulating in Hollywood drew a $600,000 offer for the movie rights. D Seuss’s first children’s book, *And to Think That I Saw It on Mulberry Street*, was rejected by twent seven publishers. And J. K. Rowling’s first *Harry Potter* manuscript was rejected by nine.[8] Then the is the other side of the coin—the side anyone in the business knows all too well: the many authors wh had great potential but never made it, John Grishams who quit after the first twenty rejections or J. Rowlings who gave up after the first five. After his many rejections, one such writer, John Kenned Toole, lost hope of ever getting his novel published and committed suicide. His mother persevere however, and eleven years later *A Confederacy of Dunces* was published; it won the Pulitzer Prize f Fiction and has sold nearly 2 million copies.

There exists a vast gulf of randomness and uncertainty between the creation of a great novel— piece of jewelry or chocolate-chip cookie—and the presence of huge stacks of that novel—or jewel or bags of cookies—at the front of thousands of retail outlets. That’s why successful people in ever field are almost universally members of a certain set—the set of people who don’t give up.

A lot of what happens to us—success in our careers, in our investments, and in our life decision both major and minor—is as much the result of random factors as the result of skill, preparedness, an hard work. So the reality that we perceive is not a direct reflection of the people or circumstances th underlie it but is instead an image blurred by the randomizing effects of unforeseeable or fluctuatin external forces. That is not to say that ability doesn’t matter—it is one of the factors that increase th chances of success—but the connection between actions and results is not as direct as we might like believe. Thus our past is not so easy to understand, nor is our future so easy to predict, and in bo enterprises we benefit from looking beyond the superficial explanations.

WE HABITUALLY UNDERESTIMATE THE EFFECTS of randomness. Our stockbroker recommends that w invest in the Latin American mutual fund that “beat the pants off the domestic funds” five yea running. Our doctor attributes that increase in our triglycerides to our new habit of enjoying a Hoste Ding Dong with milk every morning after dutifully feeding the kids a breakfast of mangoes and nonf yogurt. We may or may not take our stockbroker’s or doctor’s advice, but few of us question whethe he or she has enough data to give it. In the political world, the economic world, the business world-even when careers and millions of dollars are at stake—chance events are often conspicuous misinterpreted as accomplishments or failures.

Hollywood provides a nice illustration. Are the rewards (and punishments) of the Hollywood gam deserved, or does luck play a far more important role in box office success (and failure) than peop imagine? We all understand that genius doesn't guarantee success, but it's seductive to assume tha success must come from genius. Yet the idea that no one can know in advance whether a film will h or miss has been an uncomfortable suspicion in Hollywood at least since the novelist and screenwrit William Goldman enunciated it in his classic 1983 book *Adventures in the Screen Trade.* In that boo Goldman quoted the former studio executive David Picker as saying, "If I had said yes to all th projects I turned down, and no to all the other ones I took, it would have worked out about the same."

That's not to say that a jittery homemade horror video could become a hit just as easily as, sa *Exorcist: The Beginning,* which cost an estimated $80 million. Well, actually, that is what happene some years back with *The Blair Witch Project:* it cost the filmmakers a mere $60,000 but brought $140 million in domestic box office revenue—more than three times the business of *Exorcist.* Sti that's not what Goldman was saying. He was referring only to professionally made Hollywood film with production values good enough to land the film a respectable distributor. And Goldman didn deny that there are reasons for a film's box office performance. But he did say that those reasons a so complex and the path from green light to opening weekend so vulnerable to unforeseeable an uncontrollable influences that educated guesses about an unmade film's potential aren't much bett than flips of a coin.

Examples of Hollywood's unpredictability are easy to find. Movie buffs will remember the gre expectations the studios had for the megaflops *Ishtar* (Warren Beatty + Dustin Hoffman + a $5 million budget = $14 million in box office revenue) and *Last Action Hero* (Arnold Schwarzenegger $85 million = $50 million). On the other hand, you might recall the grave doubts that executives Universal Studios had about the young director George Lucas's film *American Graffiti,* shot for le than $1 million. Despite their skepticism, it took in $115 million, but still that didn't stop them fro having even graver doubts about Lucas's next idea. He called the story *Adventures of Luke Starkille as taken from "The Journal of the Whills."* Universal called it unproducible. Ultimately 20th Centu Fox made the film, but the studio's faith in the project went only so far: it paid Lucas just $200,000 write and direct it; in exchange, Lucas received the sequel and merchandising rights. In the end, *St Wars* took in $461 million on a budget of $13 million, and Lucas had himself an empire.

Given the fact that green light decisions are made years before a film is completed and films a subject to many unpredictable factors that arise during those years of production and marketing, not mention the inscrutable tastes of the audience, Goldman's theory doesn't seem at all far-fetched. (It also one that is supported by much recent economic research.)[10] Despite all this, studio executives a not judged by the bread-and-butter management skills that are as essential to the head of the Unite States Steel Corporation as they are to the head of Paramount Pictures. Instead, they are judged b their ability to pick hits. If Goldman is right, that ability is mere illusion, and in spite of his or h swagger no executive is worth that $25 million contract.

Deciding just how much of an outcome is due to skill and how much to luck is not a no-braine Random events often come like the raisins in a box of cereal—in groups, streaks, and clusters. An

although Fortune is fair in potentialities, she is not fair in outcomes. That means that if each of 1
~~Hollywood executives tosses 10 coins, although each has an equal chance of being the winner~~ or th
loser, in the end there *will* be winners and losers. In this example, the chances are 2 out of 3 that
least 1 of the executives will score 8 or more heads or tails.

Imagine that George Lucas makes a new *Star Wars* film and in one test market decides to perform
crazy experiment. He releases the identical film under two titles: *Star Wars: Episode A* and *St
Wars: Episode B.* Each film has its own marketing campaign and distribution schedule, with th
corresponding details identical except that the trailers and ads for one film say *Episode A* and tho
for the other, *Episode B.* Now we make a contest out of it. Which film will be more popular? Say w
look at the first 20,000 moviegoers and record the film they choose to see (ignoring those die-ha
fans who will go to both and then insist there were subtle but meaningful differences between th
two). Since the films and their marketing campaigns are identical, we can mathematically model th
game this way: Imagine lining up all the viewers in a row and flipping a coin for each viewer in tur
If the coin lands heads up, he or she sees *Episode A;* if the coin lands tails up, it's *Episode B.* Becau
the coin has an equal chance of coming up either way, you might think that in this experimental bo
office war each film should be in the lead about half the time. But the mathematics of randomne
says otherwise: the most probable number of changes in the lead is 0, and it is 88 times more probab
that one of the two films will lead through all 20,000 customers than it is that, say, the lea
continuously seesaws.[11] The lesson is not that there is no difference between films but that some film
will do better than others even if all the films are identical.

Such issues are not discussed in corporate boardrooms, in Hollywood, or elsewhere, and so th
typical patterns of randomness—apparent hot or cold streaks or the bunching of data into clusters-
are routinely misinterpreted and, worse, acted on as if they represented a new trend.

One of the most high profile examples of anointment and regicide in modern Hollywood was th
case of Sherry Lansing, who ran Paramount with great success for many years.[12] Under Lansin
Paramount won Best Picture awards for *Forrest Gump, Braveheart,* and *Titanic* and posted its tw
highest-grossing years ever. Then Lansing's reputation suddenly plunged, and she was dumped afte
Paramount experienced, as *Variety* put it, "a long stretch of underperformance at the box office."[13]

In mathematical terms there is both a short and a long explanation for Lansing's fate. First, th
short answer. Look at this series of percentages: 11.4, 10.6, 11.3, 7.4, 7.1, 6.7. Notice something
Lansing's boss, Sumner Redstone, did too, and for him the trend was significant, for those s
numbers represented the market share of Paramount's Motion Picture Group for the final six years o
Lansing's tenure. The trend caused *BusinessWeek* to speculate that Lansing "may simply no long
have Hollywood's hot hand."[14] Soon Lansing announced she was leaving, and a few months later
talent manager named Brad Grey was brought on board.

How can a surefire genius lead a company through seven great years and then fail practical
overnight? There were plenty of theories explaining Lansing's early success. While Paramount wa
doing well, Lansing was praised for making it one of Hollywood's best-run studios and for her knac
for turning conventional stories into $100 million hits. When her fortune changed, the revisionis
took over. Her penchant for making successful remakes and sequels became a drawback. Mo
damning of all, perhaps, was the notion that her failure was due to her "middle-of-the-road tastes

She was now blamed for green-lighting such box office dogs as *Timeline* and *Lara Croft Tomb Raide* *The Cradle of Life*. Suddenly the conventional wisdom was that Lansing was risk averse, ol fashioned, and out of touch with the trends. But can she really be blamed for thinking that a Micha Crichton bestseller would be promising movie fodder? And where were all the *Lara Croft* critics wh the first *Tomb Raider* film took in $131 million in box office revenue?

Even if the theories of Lansing's shortcomings were plausible, consider how abruptly her demi occurred. Did she become risk averse and out of touch overnight? Because Paramount's market sha plunged that suddenly. One year Lansing was flying high; the next she was a punch line for late-nig comedians. Her change of fortune might have been understandable if, like others in Hollywood, s had become depressed over a nasty divorce proceeding, had been charged with embezzlement, or h joined a religious cult. That was not the case. And she certainly hadn't sustained any damage to h cerebral cortex. The only evidence of Lansing's newly developed failings that her critics could off was, in fact, her newly developed failings.

In hindsight it is clear that Lansing was fired because of the industry's misunderstanding randomness and not because of her flawed decision making: Paramount's films for the following ye were already in the pipeline when Lansing left the company. So if we want to know roughly ho Lansing would have done in some parallel universe in which she remained in her job, all we need to is look at the data in the year following her departure. With such films as *War of the Worlds* and *T* *Longest Yard*, Paramount had its best summer in a decade and saw its market share rebound to near 10 percent. That isn't merely ironic—it's again that aspect of randomness called regression toward t mean. A *Variety* headline on the subject read, "Parting Gifts: Old Regime's Pics Fuel Paramou Rebound,"[15] but one can't help but think that had Viacom (Paramount's parent company) had mo patience, the headline might have read, "Banner Year Puts Paramount and Lansing's Career Back Track."

Sherry Lansing had good luck at the beginning and bad luck at the end, but it could have bee worse. She could have had her bad luck at the beginning. That's what happened to a Columbia Pictur chief named Mark Canton. Described as box office savvy and enthusiastic shortly after he was hire he was fired after his first few years produced disappointing box office results. Criticized by o unnamed colleague for being "incapable of distinguishing the winners from the losers" and by anoth for being "too busy cheerleading," this disgraced man left in the pipeline when he departed such film as *Men in Black* ($589 million in worldwide box office revenue), *Air Force One* ($315 million), *T* *Fifth Element* ($264 million), *Jerry Maguire* ($274 million), and *Anaconda* ($137 million). As *Varie* put it, Canton's legacy pictures "hit and hit big."[16]

Well, that's Hollywood, a town where Michael Ovitz works as Disney president for fifteen month and then leaves with a $140 million severance package and where the studio head David Begelman fired by Columbia Pictures for forgery and embezzlement and then is hired a few years later as CE of MGM. But as we'll see in the following chapters, the same sort of misjudgments that plag Hollywood also plague people's perceptions in all realms of life.

My own epiphany regarding the hidden effects of randomness came in college, when I took a course ~~probability and began applying its principles to the sports world. That is easy to do because~~, as in th film business, most accomplishments in sports are easily quantified and the data are readily availabl What I discovered was that just as the lessons of persistence, practice, and teamwork that we lea from sports apply equally to all endeavors of life, so do the lessons of randomness. And so I set out examine a tale of two baseball sluggers, Roger Maris and Mickey Mantle, a tale that bears a lesson f all of us, even those who wouldn't know a baseball from a Ping-Pong ball.

The year was 1961. I was barely of reading age, but I still recall the faces of Maris and his mo popular New York Yankees teammate, Mantle, on the cover of *Life* magazine. The two baseba players were engaged in a historic race to tie or break Babe Ruth's beloved 1927 record of 60 hom runs in one year. Those were idealistic times when my teacher would say things like "we need mo heroes like Babe Ruth," or "we never had a crooked president." Because the legend of Babe Ruth w sacred, anyone who might challenge it had better be worthy. Mantle, a courageous perennial slugg who fought on despite bad knees, was the fans'—and the press's—overwhelming favorite. A good looking, good-natured fellow, Mantle came across as the kind of all-American boy everyone hope would set records. Maris, on the other hand, was a gruff, private fellow, an underdog who had nev hit more than 39 home runs in a year, much less anywhere near 60. He was seen as a nasty so someone who didn't give interviews and didn't like kids. They all rooted for Mantle. I liked Maris.

As it turned out, Mantle's knees got the best of him, and he made it to only 54 home runs. Mar broke Ruth's record with 61. Over his career, Babe Ruth had hit 50 or more home runs in a season fo times and twelve times had hit more than anyone else in the league. Maris never again hit 50 or eve 40 and never again led the league. That overall performance fed the resentment. As the years went b Maris was criticized relentlessly by fans, sportswriters, and sometimes other players. Their verdict: had crumbled under the pressure of being a champion. Said one famous baseball old-timer, "Maris ha no right to break Ruth's record."[17] That may have been true, but not for the reason the old-tim thought.

Many years later, influenced by that college math course, I would learn to think about Maris achievement in a new light. To analyze the Ruth-Mantle race I reread that old *Life* article and found it a brief discussion of probability theory[18] and how it could be used to predict the result of the Mari Mantle race. I decided to make my own mathematical model of home run hitting. Here's how it goe The result of any particular at bat (that is, an opportunity for success) depends primarily on th player's ability, of course. But it also depends on the interplay of many other factors: his health; th wind, the sun, or the stadium lights; the quality of the pitches he receives; the game situation; wheth he correctly guesses how the pitcher will throw; whether his hand-eye coordination works ju perfectly as he takes his swing; whether that brunette he met at the bar kept him up too late or th chili-cheese dog with garlic fries he had for breakfast soured his stomach. If not for all th unpredictable factors, a player would either hit a home run on every at bat or fail to do so. Instead, f each at bat all you can say is that he has a certain probability of hitting a home run and a certa probability of failing to hit one. Over the hundreds of at bats he has each year, those random facto usually average out and result in some typical home run production that increases as the play becomes more skillful and then eventually decreases owing to the same process that etches wrinkles his handsome face. But sometimes the random factors don't average out. How often does that happe and how large is the aberration?

From the player's yearly statistics you can estimate his probability of hitting a home run at eac opportunity—that is, on each trip to the plate.[19] In 1960, the year before his record year, Roger Mar hit 1 home run for every 14.7 opportunities (about the same as his home run output averaged over h four prime years). Let's call this performance normal Maris. You can model the home run hitting ski of normal Maris this way: Imagine a coin that comes up heads on average not 1 time every 2 toss but 1 time every 14.7. Then flip that coin 1 time for every trip to the plate and award Maris 1 hom run every time the coin comes up heads. If you want to match, say, Maris's 1961 season, you flip th coin once for every home run opportunity he had that year. By that method you can generate a who series of alternative 1961 seasons in which Maris's skill level matches the home run totals of norma Maris. The results of those mock seasons illustrate the range of accomplishment that normal Mar could have expected in 1961 if his talent had not spiked—that is, given only his "normal" home ru ability plus the effects of pure luck.

To have actually performed this experiment, I'd have needed a rather odd coin, a rather stron wrist, and a leave of absence from college. In practice the mathematics of randomness allowed me do the analysis employing equations and a computer. In most of my imaginary 1961 seasons, norm Maris's home run output was, not surprisingly, in the range that was normal for Maris. Some moc seasons he hit a few more, some a few less. Only rarely did he hit a lot more or a lot less. Ho frequently did normal Maris's talent produce Ruthian results?

I had expected normal Maris's chances of matching Ruth's record to be roughly equal to Jac Whittaker's when he plopped down an extra dollar as he bought breakfast biscuits at a convenien store a few years back and ended up winning $314 million in his state Powerball lottery. That's what less talented player's chances would have been. But normal Maris, though not Ruthian, was still f above average at hitting home runs. And so normal Maris's probability of producing a record outp by chance was not microscopic: he matched or broke Ruth's record about 1 time every 32 season That might not sound like good odds, and you probably wouldn't have wanted to bet on either Maris the year 1961 in particular. But those odds lead to a striking conclusion. To see why, let's now ask more interesting question. Let's consider *all* players with the talent of normal Maris and the *enti* seventy-year period from Ruth's record to the start of the "steroid era" (when, because of player drug use, home runs became far more common). What are the odds that *some* player at *some* tin would have matched or broken Ruth's record by chance alone? Is it reasonable to believe that Mar just happened to be the recipient of the lucky aberrant season?

History shows that in that period there was about 1 player every 3 years with both the talent and th opportunities comparable to those of normal Maris in 1961. When you add it all up, that makes th probability that by chance alone one of those players would have matched or broken Ruth's record little greater than 50 percent. In other words, over a period of seventy years a random spike of 60 more home runs for a player whose production process merits more like 40 home runs is to b expected—a phenomenon something like that occasional loud crackle you hear amid the static in bad telephone connection. It is also to be expected, of course, that we will deify, or vilify—an certainly endlessly analyze—whoever that "lucky" person turns out to be.

We can never know for certain whether Maris was a far better player in 1961 than in any of th other years he played professional baseball or whether he was merely the beneficiary of good fortun But ~~detailed analyses of baseball and other sports by scientists as eminent as the late Stephen~~ Ja Gould and the Nobel laureate E. M. Purcell show that coin-tossing models like the one I've describe match very closely the actual performance of both players and teams, including their hot and co streaks.[20]

When we look at extraordinary accomplishments in sports—or elsewhere—we should keep in mi that extraordinary events can happen without extraordinary causes. Random events often look li nonrandom events, and in interpreting human affairs we must take care not to confuse the two. Thoug it has taken many centuries, scientists have learned to look beyond apparent order and recognize th hidden randomness in both nature and everyday life. In this chapter I've presented a few glimpses those workings. In the following chapters I shall consider the central ideas of randomness within the historical context and describe their relevance with the aim of offering a new perspective on o everyday surroundings and hence a better understanding of the connection between this fundament aspect of nature and our own experience.

CHAPTER 2

The Laws of Truths and Half-Truths

LOOKING TO THE SKY on a clear, moonless night, the human eye can detect thousands of twinklin sources of light. Nestled among those haphazardly scattered stars are patterns. A lion here, a dipp there. The ability to detect patterns can be both a strength and a weakness. Isaac Newton pondered th patterns of falling objects and created a law of universal gravitation. Others have noted a spike in the athletic performance when they are wearing dirty socks and thenceforth have refused to wear clea ones. Among all the patterns of nature, how do we distinguish the meaningful ones? Drawing th distinction is an inherently practical enterprise. And so it might not astonish you to learn that, unlik geometry, which arose as a set of axioms, proofs, and theorems created by a culture of ponderou philosophers, the theory of randomness sprang from minds focused on spells and gambling, figures w might sooner imagine with dice or a potion in hand than a book or a scroll.

The theory of randomness is fundamentally a codification of common sense. But it is also a field subtlety, a field in which great experts have been famously wrong and expert gamblers infamousl correct. What it takes to understand randomness and overcome our misconceptions is both experienc and a lot of careful thinking. And so we begin our tour with some of the basic laws of probability an the challenges involved in uncovering, understanding, and applying them. One of the classi explorations of people's intuition about those laws was an experiment conducted by the pair who d so much to elucidate our misconceptions, Daniel Kahneman and Amos Tversky.[1] Feel free to take pa —and learn something about your own probabilistic intuition.

Imagine a woman named Linda, thirty-one years old, single, outspoken, and very bright. In colleg she majored in philosophy. While a student she was deeply concerned with discrimination and soci justice and participated in antinuclear demonstrations. Tversky and Kahneman presented th description to a group of eighty-eight subjects and asked them to rank the following statements on scale of 1 to 8 according to their probability, with 1 representing the most probable and 8 the leas Here are the results, in order from most to least probable:

Statement	*Average Probability Rank*
Linda is active in the feminist movement.	2.1
Linda is a psychiatric social worker.	3.1
Linda works in a bookstore and takes yoga classes.	3.3

Linda is a bank teller and is active in the feminist movement.	4.1
Linda is a teacher in an elementary school.	5.2
Linda is a member of the League of Women Voters.	5.4
Linda is a bank teller.	6.2
Linda is an insurance salesperson.	6.4

At first glance there may appear to be nothing unusual in these results: the description was in fa designed to be representative of an active feminist and unrepresentative of a bank teller or a insurance salesperson. But now let's focus on just three of the possibilities and their average rank listed below in order from most to least probable. This is the order in which 85 percent of th respondents ranked the three possibilities:

Statement	*Average Probability Rank*
Linda is active in the feminist movement.	2.1
Linda is a bank teller and is active in the feminist movement.	4.1
Linda is a bank teller.	6.2

If nothing about this looks strange, then Kahneman and Tversky have fooled you, for if the chanc that Linda is a bank teller and is active in the feminist movement were greater than the chance th Linda is a bank teller, there would be a violation of our first law of probability, which is one of th most basic of all: *The probability that two events will both occur can never be greater than th probability that each will occur individually.* Why not? Simple arithmetic: the chances that event will occur = the chances that events A and B will occur + the chance that event A will occur and even B *will not* occur.

Kahneman and Tversky were not surprised by the result because they had given their subjects large number of possibilities, and the connections among the three scenarios could easily have gotte lost in the shuffle. And so they presented the description of Linda to another group, but this time the presented only these possibilities:

Linda is active in the feminist movement.

Linda is a bank teller and is active in the feminist movement.

Linda is a bank teller.

To their surprise, 87 percent of the subjects in this trial also ranked the probability that Linda is bank teller and is active in the feminist movement higher than the probability that Linda is a ban teller. And so the researchers pushed further: they explicitly asked a group of thirty-six fairl sophisticated graduate students to consider their answers in light of our first law of probability. Eve after the prompting, two of the subjects clung to the illogical response.

The interesting thing that Kahneman and Tversky noticed about this stubborn misperception is th people will not make the same mistake if you ask questions that are unrelated to what they know abo Linda. For example, suppose Kahneman and Tversky had asked which of these statements seems mo probable:

Linda owns an International House of Pancakes franchise.

Linda had a sex-change operation and is now known as Larry.

Linda had a sex-change operation, is now known as Larry, and owns an International House of Pancakes franchise.

In this case few people would choose the last option as more likely than either of the other two.

Kahneman and Tversky concluded that because the detail “Linda is active in the femini movement” rang true based on the initial description of her character, when they added that detail the bank-teller speculation, it increased the scenario’s credibility. But a lot could have happene between Linda’s hippie days and her fourth decade on the planet. She might have undergone conversion to a fundamentalist religious cult, married a skinhead and had a swastika tattooed on h left buttock, or become too busy with other aspects of her life to remain politically active. In each these cases and many others she would probably not be active in the feminist movement. So addin that detail lowered the chances that the scenario was accurate even though it appeared to raise th chances of its accuracy.

If the details we are given fit our mental picture of something, then the more details in a scenari the more real it seems and hence the more probable we consider it to be—even though any act adding less-than-certain details to a conjecture makes the conjecture less probable. This inconsistenc between the logic of probability and people’s assessments of uncertain events interested Kahnema and Tversky because it can lead to unfair or mistaken assessments in real-life situations. Which ~~more likely: that a defendant, after discovering the body, left the scene of the crime or~~ that defendant, after discovering the body, left the scene of the crime because he feared being accused the grisly murder? Is it more probable that the president will increase federal aid to education or th he or she will increase federal aid to education with funding freed by cutting other aid to the states? it more likely that your company will increase sales next year or that it will increase sales next ye because the overall economy has had a banner year? In each case, even though the latter is le probable than the former, it may sound more likely. Or as Kahneman and Tversky put it, "A goo story is often less probable than a less satisfactory…[explanation]."

Kahneman and Tversky found that even highly trained doctors make this error.[2] They presented group of internists with a serious medical problem: a pulmonary embolism (a blood clot in the lung If you have that ailment, you might display one or more of a set of symptoms. Some of tho symptoms, such as partial paralysis, are uncommon; others, such as shortness of breath, are probabl Which is more likely: that the victim of an embolism will experience only partial paralysis or that th victim will experience both partial paralysis and shortness of breath? Kahneman and Tversky foun that 91 percent of the doctors believed a clot was less likely to cause just a rare symptom than it w to cause a combination of the rare symptom and a common one. (In the doctors' defense, patien don't walk into their offices and say things like "I have a blood clot in my lungs. Guess m symptoms.")

Years later one of Kahneman's students and another researcher found that attorneys fall prey to th same bias in their judgments.[3] Whether involved in a criminal case or a civil case, clients typical depend on their lawyers to assess what may occur if their case goes to trial. What are the chances acquittal or of a settlement or a monetary judgment in various amounts? Although attorneys might n phrase their opinions in terms of numerical probabilities, they offer advice based on their person forecast of the relative likelihood of the possible outcomes. Here, too, the researchers found th lawyers assign higher probabilities to contingencies that are described in greater detail. For exampl at the time of the civil lawsuit brought by Paula Jones against then president Bill Clinton, 2 practicing lawyers were asked to predict the probability that the trial would not run its full course. F some of the subjects that possibility was broken down into specific causes for the trial's early en such as settlement, withdrawal of the charges, or dismissal by the judge. In comparing the two grou —lawyers who had simply been asked to predict whether the trial would run its full course a lawyers who had been presented with ways in which the trial might reach a premature conclusion—t researchers found that the lawyers who had been presented with causes of a premature conclusi were much more likely than the other lawyers to predict that the trial would reach an early end.

The ability to evaluate meaningful connections among different phenomena in our environme may be so important that it is worth seeing a few mirages. If a starving caveman sees an indistin greenish blur on a distant rock, it is more costly to dismiss it as uninteresting when it is in reality plump, tasty lizard than it is to race over and pounce on what turns out to be a few stray leaves. A so, that theory goes, we might have evolved to avoid the former mistake at the cost of sometim making the latter.

In the story of mathematics the ancient Greeks stand out as the inventors of the manner in whic modern mathematics is carried out: through axioms, proofs, theorems, more proofs, more theorem and so on. In the 1930s, however, the Czech American mathematician Kurt Gödel—a friend o Einstein's—showed this approach to be somewhat deficient: most of mathematics, he demonstrate must be inconsistent or else must contain truths that cannot be proved. Still, the march of mathemati has continued unabated in the Greek style, the style of Euclid. The Greeks, geniuses in geometr created a small set of axioms, statements to be accepted without proof, and proceeded from there prove many beautiful theorems detailing the properties of lines, planes, triangles, and other geometr forms. From this knowledge they discerned, for example, that the earth is a sphere and even calculate its radius. One must wonder why a civilization that could produce a theorem such as proposition 29 book 1 of Euclid's *Elements*—"a straight line falling on two parallel straight lines makes the alterna angles equal to one another, the exterior angle equal to the interior and opposite angle, and the interi angles on the same side equal to two right angles"—did not create a theory showing that if you thro two dice, it would be unwise to bet your Corvette on their both coming up a 6.

Actually, not only didn't the Greeks have Corvettes, but they also didn't have dice. They did hav gambling addictions, however. They also had plenty of animal carcasses, and so what they tossed we astragali, made from heel bones. An astragalus has six sides, but only four are stable enough to allo the bone to come to rest on them. Modern scholars note that because of the bone's construction, th chances of its landing on each of the four sides are not equal: they are about 10 percent for two of th sides and 40 percent for the other two. A common game involved tossing four astragali. The outcom considered best was a rare one, but not the rarest: the case in which all four astragali came u different. This was called a Venus throw. The Venus throw has a probability of about 384 out o 10,000, but the Greeks, lacking a theory of randomness, didn't know that.

The Greeks also employed astragali when making inquiries of their oracles. From their oracle questioners could receive answers that were said to be the words of the gods. Many important choic made by prominent Greeks were based on the advice of oracles, as evidenced by the accounts of th historian Herodotus, and writers like Homer, Aeschylus, and Sophocles. But despite the importance o astragali tosses in both gambling and religion, the Greeks made no effort to understand the regulariti of astragali throws.

Why didn't the Greeks develop a theory of probability? One answer is that many Greeks believe that the future unfolded according to the will of the gods. If the result of an astragalus toss mea "marry the stocky Spartan girl who pinned you in that wrestling match behind the school barracks," Greek boy wouldn't view the toss as the lucky (or unlucky) result of a random process; he would vie it as the gods' will. Given such a view, an understanding of randomness would have been irrelevan Thus a mathematical prediction of randomness would have seemed impossible. Another answer ma lie in the very philosophy that made the Greeks such great mathematicians: they insisted on absolu truth, proved by logic and axioms, and frowned on uncertain pronouncements. In Plato's *Phaedo,* f example, Simmias tells Socrates that "arguments from probabilities are impostors" and anticipates th work of Kahneman and Tversky by pointing out that "unless great caution is observed in the use them they are apt to be deceptive—in geometry, and in other things too."[4] And in *Theaetetus,* Socrat says that any mathematician "who argued from probabilities and likelihoods in geometry would not b worth an ace."[5] But even Greeks who believed that probabilists were worth an ace might have ha difficulty working out a consistent theory in those days before extensive record keeping becau ~~people have notoriously poor memories when it comes to estimating the frequency—and hence~~ th probability—of past occurrences.

Which is greater: the number of six-letter English words having *n* as their fifth letter or the numb of six-letter English words ending in *ing*? Most people choose the group of words ending in *ing* Why? Because words ending in *ing* are easier to think of than generic six-letter words having *n* their fifth letter. But you don't have to survey the *Oxford English Dictionary*—or even know how count—to prove that guess wrong: the group of six-letter words having *n* as their fifth letter wor *includes* all six-letter words ending in *ing*. Psychologists call that type of mistake the availability bi because in reconstructing the past, we give unwarranted importance to memories that are most viv and hence most available for retrieval.

The nasty thing about the availability bias is that it insidiously distorts our view of the world b distorting our perception of past events and our environment. For example, people tend overestimate the fraction of homeless people who are mentally ill because when they encounter homeless person who is not behaving oddly, they don't take notice and tell all their friends about th unremarkable homeless person they ran into. But when they encounter a homeless person stompi down the street and waving his arms at an imaginary companion while singing "When the Saints C Marching In," they do tend to remember the incident.[7] How probable is it that of the five lines at th grocery-store checkout you will choose the one that takes the longest? Unless you've been cursed by practitioner of the black arts, the answer is around 1 in 5. So why, when you look back, do you get th feeling you have a supernatural knack for choosing the longest line? Because you have more importa things to focus on when things go right, but it makes an impression when the lady in front of you wi a single item in her cart decides to argue about why her chicken is priced at $1.50 a pound when she certain the sign at the meat counter said $1.49.

One stark illustration of the effect the availability bias can have on our judgment and decisio making came from a mock jury trial.[8] In the study the jury was given equal doses of exonerating a incriminating evidence regarding the charge that a driver was drunk when he ran into a garbage truc The catch is that one group of jurors was given the exonerating evidence in a "pallid" version: "T owner of the garbage truck stated under cross-examination that his garbage truck was difficult to s at night because it was gray in color." The other group was given a more "vivid" form of the sam evidence: "The owner of the garbage truck stated under cross-examination that his garbage truck w difficult to see at night because it was gray in color. The owner remarked his trucks are gray 'becau it hides the dirt. What do you want, I should paint 'em pink?'" The incriminating evidence was als presented in two ways, this time in a vivid form to the first group and in a pallid version to the secon When the jurors were asked to produce guilt/innocence ratings, the side with the more viv presentation of the evidence always prevailed, and the effect was enhanced when there was a fort eight-hour delay before rendering the verdict (presumably because the recall gap was even greater).

By distorting our view of the past, the availability bias complicates any attempt to make sense of That was true for the ancient Greeks just as it is true for us. But there was one other major obstacle an early theory of randomness, a very practical one: although basic probability requires on knowledge of arithmetic, the Greeks did not know arithmetic, at least not in a form that is easy work with. In Athens in the fifth century B.C., for instance, at the height of Greek civilization, a pers