

I

There's Someone In My Head, But It's Not Me

Take a close look at yourself in the mirror. Beneath your dashing good looks churns a hidden universe of networked machinery. The machinery includes a sophisticated scaffolding of interlocking bones, a netting of sinewy muscles, a good deal of specialized fluid, and a collaboration of internal organs chugging away in darkness to keep you alive. A sheet of high-tech self-healing sensory material that we call skin seamlessly covers your machinery in a pleasing package.

And then there's your brain. Three pounds of the most complex material we've discovered in the universe. This is the mission control center that drives the whole operation, gathering dispatches through small portals in the armored bunker of the skull.

Your brain is built of cells called neurons and glia—hundreds of billions of them. Each one of these cells is as complicated as a city. And each one contains the entire human genome and traffics billions of molecules in intricate economies. Each cell sends electrical pulses to other cells, up to hundreds of times per second. If you represented each of these trillions and trillions of pulses in your brain by a single photon of light, the combined output would be blinding.

The cells are connected to one another in a network of such staggering complexity that it bankrupts human language and necessitates new strains of mathematics. A typical neuron makes about ten thousand connections to neighboring neurons. Given the

billions of neurons, this means there are as many connections in a single cubic centimeter of brain tissue as there are stars in the Milky Way galaxy.

The three-pound organ in your skull—with its pink consistency of Jell-o—is an alien kind of computational material. It is composed of miniaturized, self-configuring parts, and it vastly outstrips anything we've dreamt of building. So if you ever feel lazy or dull, take heart: you're the busiest, brightest thing on the planet.

Ours is an incredible story. As far as anyone can tell, we're the only system on the planet so complex that we've thrown ourselves headlong into the game of deciphering our own programming language. Imagine that your desktop computer began to control its own peripheral devices, removed its own cover, and pointed its webcam at its own circuitry. That's us.

And what we've discovered by peering into the skull ranks among the most significant intellectual developments of our species: the recognition that the innumerable facets of our behavior, thoughts, and experience are inseparably yoked to a vast, wet, chemical-electrical network called the nervous system. The machinery is utterly alien to us, and yet, somehow, it *is* us.

THE TREMENDOUS MAGIC

In 1949, Arthur Alberts traveled from his home in Yonkers, New York, to villages between the Gold Coast and Timbuktu in West Africa. He brought his wife, a camera, a jeep, and—because of his love of music—a jeep-powered tape recorder. Wanting to open the ears of the western world, he recorded some of the most important music ever to come out of Africa.¹ But Alberts ran into social troubles while using the tape recorder. One West African native heard his voice played back and accused Alberts of “stealing his tongue.” Alberts only narrowly averted being pummeled by taking out a mirror and convincing the man that his tongue was still intact.

It's not difficult to see why the natives found the tape recorder so counterintuitive. A vocalization seems ephemeral and ineffable: it is like opening a bag of feathers which scatter on the breeze and can never be retrieved. Voices are weightless and odorless, something you cannot hold in your hand.

So it comes as a surprise that a voice *is* physical. If you build a little machine sensitive enough to detect tiny compressions of the molecules in the air, you can capture these density changes and reproduce them later. We call these machines microphones, and every one of the billions of radios on the planet is proudly serving up bags of feathers once thought irretrievable. When Alberts played the music back from the tape recorder, one West African tribesman depicted the feat as "tremendous magic."

And so it goes with thoughts. What exactly is a thought? It doesn't seem to weigh anything. It feels ephemeral and ineffable. You wouldn't think that a thought has a shape or smell or any sort of physical instantiation. Thoughts seem to be a kind of tremendous magic.

But just like voices, thoughts are underpinned by physical stuff. We know this because alterations to the brain change the kinds of thoughts we can think. In a state of deep sleep, there are no thoughts. When the brain transitions into dream sleep, there are unbidden, bizarre thoughts. During the day we enjoy our normal, well-accepted thoughts, which people enthusiastically modulate by spiking the chemical cocktails of the brain with alcohol, narcotics, cigarettes, coffee, or physical exercise. The state of the physical material determines the state of the thoughts.

And the physical material is absolutely necessary for normal thinking to tick along. If you were to injure your pinkie in an accident you'd be distressed, but your conscious experience would be no different. By contrast, if you were to damage an equivalently sized piece of brain tissue, this might change your capacity to understand music, name animals, see colors, judge risk, make decisions, read signals from your body, or understand the concept of a mirror—thereby unmasking the strange, veiled workings of

the machinery beneath. Our hopes, dreams, aspirations, fears, comic instincts, great ideas, fetishes, senses of humor, and desires all emerge from this strange organ—and when the brain changes, so do we. So although it's easy to intuit that thoughts don't have a physical basis, that they are something like feathers on the wind, they in fact depend directly on the integrity of the enigmatic, three-pound mission control center.

The first thing we learn from studying our own circuitry is a simple lesson: most of what we do and think and feel is not under our conscious control. The vast jungles of neurons operate their own programs. The conscious you—the *I* that flickers to life when you wake up in the morning—is the smallest bit of what's transpiring in your brain. Although we are dependent on the functioning of the brain for our inner lives, it runs its own show. Most of its operations are above the security clearance of the conscious mind. The *I* simply has no right of entry.

Your consciousness is like a tiny stowaway on a transatlantic steamship, taking credit for the journey without acknowledging the massive engineering underfoot. This book is about that amazing fact: how we know it, what it means, and what it explains about people, markets, secrets, strippers, retirement accounts, criminals, artists, Ulysses, drunkards, stroke victims, gamblers, athletes, bloodhounds, racists, lovers, and every decision you've ever taken to be yours.

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In a recent experiment, men were asked to rank how attractive they found photographs of different women's faces. The photos were eight by ten inches, and showed women facing the camera or turned in three-quarter profile. Unbeknownst to the men, in half the photos the eyes of the women were dilated, and in the other half they were not. The men were consistently more attracted to the women with dilated eyes. Remarkably, the men had no insight into their decision making. None of them said, "I noticed her pupils were

two millimeters larger in this photo than in this other one.” Instead, they simply felt more drawn toward some women than others, for reasons they couldn’t quite put a finger on.

So who was doing the choosing? In the largely inaccessible workings of the brain, *something* knew that a woman’s dilated eyes correlates with sexual excitement and readiness. Their brains knew this, but the men in the study didn’t—at least not explicitly. The men may also not have known that their notions of beauty and feelings of attraction are deeply hardwired, steered in the right direction by programs carved by millions of years of natural selection. When the men were choosing the most attractive women, they didn’t know that the choice was not theirs, *really*, but instead the choice of successful programs that had been burned deep into the brain’s circuitry over the course of hundreds of thousands of generations.

Brains are in the business of gathering information and steering behavior appropriately. It doesn’t matter whether consciousness is involved in the decision making. And most of the time, it’s not. Whether we’re talking about dilated eyes, jealousy, attraction, the love of fatty foods, or the great idea you had last week, consciousness is the smallest player in the operations of the brain. Our brains run mostly on autopilot, and the conscious mind has little access to the giant and mysterious factory that runs below it.

You see evidence of this when your foot gets halfway to the brake before you consciously realize that a red Toyota is backing out of a driveway on the road ahead of you. You see it when you notice your name spoken in a conversation across the room that you thought you weren’t listening to, when you find someone attractive without knowing why, or when your nervous system gives you a “hunch” about which choice you should make.

The brain is a complex system, but that doesn’t mean it’s incomprehensible. Our neural circuits were carved by natural selection to solve problems that our ancestors faced during our species’ evolutionary history. Your brain has been molded by evolutionary pressures just as your spleen and eyes have been. And so has

your consciousness. Consciousness developed because it was advantageous, *but advantageous only in limited amounts.*

Consider the activity that characterizes a nation at any moment. Factories churn, telecommunication lines buzz with activity, businesses ship products. People eat constantly. Sewer lines direct waste. All across the great stretches of land, police chase criminals. Handshakes secure deals. Lovers rendezvous. Secretaries field calls, teachers profess, athletes compete, doctors operate, bus drivers navigate. You may wish to know what's happening at any moment in your great nation, but you can't possibly take in all the information at once. Nor would it be useful, even if you could. You want a summary. So you pick up a newspaper—not a dense paper like the *New York Times* but lighter fare such as *USA Today*. You won't be surprised that none of the details of the activity are listed in the paper; after all, you want to know the bottom line. You want to know that Congress just signed a new tax law that affects your family, but the detailed origin of the idea—involving lawyers and corporations and filibusters—isn't especially important to that new bottom line. And you certainly wouldn't want to know all the details of the food supply of the nation—how the cows are eating and how many are being eaten—you only want to be alerted if there's a spike of mad cow disease. You don't care how the garbage is produced and packed away; you only care if it's going to end up in your backyard. You don't care about the wiring and infrastructure of the factories; you only care if the workers are going on strike. That's what you get from reading the newspaper.

Your conscious mind is that newspaper. Your brain buzzes with activity around the clock, and, just like the nation, almost everything transpires locally: small groups are constantly making decisions and sending out messages to other groups. Out of these local interactions emerge larger coalitions. By the time you read a mental headline, the important action has already transpired, the deals are done. You have surprisingly little access to what happened behind the scenes. Entire political movements gain ground-up

support and become unstoppable before you ever catch wind of them as a feeling or an intuition or a thought that strikes you. You're the last one to hear the information.

However, you're an odd kind of newspaper reader, reading the headline and taking credit for the idea as though you thought of it first. You gleefully say, "I just thought of something!", when in fact your brain performed an enormous amount of work before your moment of genius struck. When an idea is served up from behind the scenes, your neural circuitry has been working on it for hours or days or years, consolidating information and trying out new combinations. But you take credit without further wonderment at the vast, hidden machinery behind the scenes.

And who can blame you for thinking you deserve the credit? The brain works its machinations in secret, conjuring ideas like tremendous magic. It does not allow its colossal operating system to be probed by conscious cognition. The brain runs its show incognito.

So who, exactly, deserves the acclaim for a great idea? In 1862, the Scottish mathematician James Clerk Maxwell developed a set of fundamental equations that unified electricity and magnetism. On his deathbed, he coughed up a strange sort of confession, declaring that "something within him" discovered the famous equations, not he. He admitted he had no idea how ideas actually came to him—they simply came to him. William Blake related a similar experience, reporting of his long narrative poem *Milton*: "I have written this poem from immediate dictation twelve or sometimes twenty lines at a time without premeditation and even against my will." Johann Wolfgang von Goethe claimed to have written his novella *The Sorrows of Young Werther* with practically no conscious input, as though he were holding a pen that moved on its own.

And consider the British poet Samuel Taylor Coleridge. He began using opium in 1796, originally for relief from the pain of toothaches and facial neuralgia—but soon he was irreversibly hooked, swigging as much as two quarts of laudanum each week. His poem

“Kubla Khan,” with its exotic and dreamy imagery, was written on an opium high that he described as “a kind of a reverie.” For him, the opium became a way to tap into his subconscious neural circuits. We credit the beautiful words of “Kubla Khan” to Coleridge because they came from *his* brain and no else’s, right? But he couldn’t get hold of those words while sober, so who exactly does the credit for the poem belong to?

As Carl Jung put it, “In each of us there is another whom we do not know.” As Pink Floyd put it, “There’s someone in my head, but it’s not me.”

* * *

Almost the entirety of what happens in your mental life is not under your conscious control, and the truth is that it’s better this way. Consciousness can take all the credit it wants, but it is best left at the sidelines for most of the decision making that cranks along in your brain. When it meddles in details it doesn’t understand, the operation runs less effectively. Once you begin deliberating about where your fingers are jumping on the piano keyboard, you can no longer pull off the piece.

To demonstrate the interference of consciousness as a party trick, hand a friend two dry erase markers—one in each hand—and ask her to sign her name with her right hand at the same time that she’s signing it backward (mirror reversed) with her left hand. She will quickly discover that there is only one way she can do it: by *not* thinking about it. By excluding conscious interference, her hands can do the complex mirror movements with no problem—but if she thinks about her actions, the job gets quickly tangled in a bramble of stuttering strokes.

So consciousness is best left uninvited from most of the parties. When it does get included, it’s usually the last one to hear the information. Take hitting a baseball. On August 20, 1974, in a game between the California Angels and the Detroit Tigers, the *Guinness Book of World Records* clocked Nolan Ryan’s fastball

at 100.9 miles per hour (44.7 meters per second). If you work the numbers, you'll see that Ryan's pitch departs the mound and crosses home plate, sixty-feet, six inches away, in four-tenths of a second. This gives just enough time for light signals from the baseball to hit the batter's eye, work through the circuitry of the retina, activate successions of cells along the loopy superhighways of the visual system at the back of the head, cross vast territories to the motor areas, and modify the contraction of the muscles swinging the bat. Amazingly, this entire sequence is possible in less than four-tenths of a second; otherwise no one would ever hit a fastball. But the surprising part is that conscious awareness takes longer than that: about half a second, as we will see in Chapter 2. So the ball travels too rapidly for batters to be consciously aware of it. One does not need to be consciously aware to perform sophisticated motor acts. You can notice this when you begin to duck from a snapping tree branch before you are aware that it's coming toward you, or when you're already jumping up when you first become aware of the phone's ring.

The conscious mind is not at the center of the action in the brain; instead, it is far out on a distant edge, hearing but whispers of the activity.

THE UPSIDE OF DETHRONEMENT

The emerging understanding of the brain profoundly changes our view of ourselves, shifting us from an intuitive sense that we are at the center of the operations to a more sophisticated, illuminating, and wondrous view of the situation. And indeed, we've seen this sort of progress before.

On a starry night in early January 1610, a Tuscan astronomer named Galileo Galilei stayed up late, his eye pressed against the end of a tube he had designed. The tube was a telescope, and it made objects appear twenty times larger. On this night, Galileo observed Jupiter and saw what he thought were three fixed stars

near it, strung out on a line across the planet. This formation caught his attention, and he returned to it the following evening. Against his expectations, he saw that all three bodies had moved with Jupiter. That didn't compute: stars don't drift with planets. So Galileo returned his focus to this formation night after night. By January 15 he had cracked the case: these were not fixed stars but, rather, planetary bodies that revolved around Jupiter. Jupiter had moons.

With this observation, the celestial spheres shattered. According to the Ptolemaic theory, there was only a single center—the Earth—around which everything revolved. An alternative idea had been proposed by Copernicus, in which the Earth went around the sun while the moon went around the Earth—but this idea seemed absurd to traditional cosmologists because it required two centers of motion. But here, in this quiet January moment, Jupiter's moons gave testimony to multiple centers: large rocks tumbling in orbit *around* the giant planet could not also be part of the surface of celestial spheres. The Ptolemaic model in which Earth sat at the center of concentric orbits was smashed. The book in which Galileo described his discovery, *Sidereus Nuncius*, rolled off the press in Venice in March 1610 and made Galileo famous.

Six months passed before other stargazers could build instruments with sufficient quality to observe Jupiter's moons. Soon there was a major rush on the telescope-making market, and before long astronomers were spreading around the planet to make a detailed map of our place in the universe. The ensuing four centuries provided an accelerating slide from the center, depositing us firmly as a speck in the visible universe, which contains 500 million galaxy groups, 10 billion large galaxies, 100 billion dwarf galaxies, and 2,000 billion billion suns. (And the visible universe, some 15 billion light-years across, may be a speck in a far larger totality that we cannot yet see.) It is no surprise that these astonishing numbers implied a radically different story about our existence than had been previously suggested.

For many, the fall of the Earth from the center of the universe caused profound unease. No longer could the Earth be considered the paragon of creation: it was now a planet like other planets. This challenge to authority required a change in man's philosophical conception of the universe. Some two hundred years later, Johann Wolfgang von Goethe commemorated the immensity of Galileo's discovery:

Of all discoveries and opinions, none may have exerted a greater effect on the human spirit. . . . The world had scarcely become known as round and complete in itself when it was asked to waive the tremendous privilege of being the center of the universe. Never, perhaps, was a greater demand made on mankind—for by this admission so many things vanished in mist and smoke! What became of our Eden, our world of innocence, piety and poetry; the testimony of the senses; the conviction of a poetic-religious faith? No wonder his contemporaries did not wish to let all this go and offered every possible resistance to a doctrine which in its converts authorized and demanded a freedom of view and greatness of thought so far unknown, indeed not even dreamed of.

Galileo's critics decried his new theory as a dethronement of man. And following the shattering of the celestial spheres came the shattering of Galileo. In 1633 he was hauled before the Catholic Church's Inquisition, broken of spirit in a dungeon, and forced to scrawl his aggrieved signature on an Earth-centered recantation of his work.²

Galileo might have considered himself lucky. Years earlier, another Italian, Giordano Bruno, had also suggested that Earth was not the center, and in February 1600 he was dragged into the public square for his heresies against the Church. His captors, afraid that he might incite the crowd with his famed eloquence, attached an iron mask to his face to prevent him from speaking. He was burned alive at the stake, his eyes peering from behind

the mask at a crowd of onlookers who emerged from their homes to gather in the square, wanting to be at the center of things.

Why was Bruno wordlessly exterminated? How did a man with Galileo's genius find himself in shackles on a dungeon floor? Evidently, not everyone appreciates a radical shift of worldview.

If only they could know where it all led! What humankind lost in certainty and egocentrism has been replaced by awe and wonder at our place in the cosmos. Even if life on other planets is terribly unlikely—say the odds are less than one in a billion—we can still expect several billion planets to be sprouting like Chia Pets with life. And if there's only a one-in-a-million chance of life-bearing planets producing meaningful levels of intelligence (say, more than space bacteria), that would still predict several million globes with creatures intermingling in unimaginably strange civilizations. In this way, the fall from the center opened our minds to something much larger.

If you find space science fascinating, strap in for what's happening in brain science: we've been knocked from our perceived position at the center of ourselves, and a much more splendid universe is coming into focus. In this book we'll sail into that inner cosmos to investigate the alien life-forms.

FIRST GLIMPSES INTO THE VASTNESS OF INNER SPACE

Saint Thomas Aquinas (1225–1274) liked to believe that human actions came about from deliberation about what is good. But he couldn't help noticing all the things we do that have little connection with reasoned consideration—such as hiccuping, unconsciously tapping a foot to a rhythm, laughing suddenly at a joke, and so on. This was a bit of a sticking point for his theoretical framework, so he relegated all such actions to a category separate from proper human acts “since they do not proceed from the deliberation

of the reason.”³ In defining this extra category, he planted the first seed of the idea of an unconscious.

No one watered this seed for four hundred years, until the polymath Gottfried Wilhelm Leibniz (1646–1716) proposed that the mind is a melding of accessible and inaccessible parts. As a young man, Leibniz composed three hundred Latin hexameters in one morning. He then went on to invent calculus, the binary number system, several new schools of philosophy, political theories, geological hypotheses, the basis of information technology, an equation for kinetic energy, and the first seeds of the idea for software and hardware separation.⁴ With all of these ideas pouring out of him, he began to suspect—like Maxwell and Blake and Goethe—that there were perhaps deeper, inaccessible caverns inside him.

Leibniz suggested that there are some perceptions of which we are not aware, and he called these “petite perceptions.” Animals have unconscious perceptions, he conjectured—so why can’t human beings? Although the logic was speculative, he nonetheless sniffed out that something critical would be left out of the picture if we didn’t assume something like an unconscious. “Insensible perceptions are as important to [the science of the human mind] as insensible corpuscles are to natural science,” he concluded.⁵ Leibniz went on to suggest there were strivings and tendencies (“appetitions”) of which we are also unconscious but that can nonetheless drive our actions. This was the first significant exposition of unconscious urges, and he conjectured that his idea would be critical to explaining why humans behave as they do.

He enthusiastically jotted this all down in his *New Essays on Human Understanding*, but the book was not published until 1765, almost half a century after his death. The essays clashed with the Enlightenment notion of knowing oneself, and so they languished unappreciated until almost a century later. The seed sat dormant again.

In the meantime, other events were laying the groundwork for

the rise of psychology as an experimental, material science. A Scottish anatomist and theologian named Charles Bell (1774–1842) discovered that nerves—the fine radiations from the spinal cord throughout the body—were not all the same, but instead could be divided into two different kinds: motor and sensory. The former carried information out from the command center of the brain, and the latter brought information back. This was the first major discovery of a pattern to the brain’s otherwise mysterious structure, and in the hands of subsequent pioneers this led to a picture of the brain as an organ built with detailed organization instead of shadowy uniformity.

Identifying this sort of logic in an otherwise baffling three-pound block of tissue was highly encouraging, and in 1824 a German philosopher and psychologist named Johann Friedrich Herbart proposed that *ideas themselves* might be understood in a structured mathematical framework: an idea could be opposed by an opposite idea, thus weakening the original idea and causing it to sink below a threshold of awareness.⁶ In contrast, ideas that shared a similarity could support each other’s rise into awareness. As a new idea climbed, it pulled other similar ones with it. Herbart coined the term “apperceptive mass” to indicate that an idea becomes conscious not in isolation, but only in assimilation with a complex of other ideas already in consciousness. In this way, Herbart introduced a key concept: there exists a *boundary* between conscious and unconscious thoughts; we become aware of some ideas and not of others.

Against this backdrop, a German physician named Ernst Heinrich Weber (1795–1878) grew interested in bringing the rigor of physics to the study of the mind. His new field of “psychophysics” aimed to quantify what people can detect, how fast they can react, and what precisely they perceive.⁷ For the first time, perceptions began to be measured with scientific rigor, and surprises began to leak out. For example, it seemed obvious that your senses give you an accurate representation of the outside world—but by 1833 a German physiologist named Johannes Peter Müller (1801–1858)

had noticed something puzzling. If he shone light in the eye, put pressure on the eye, or electrically stimulated the nerves of the eye, all of these led to similar sensations of vision—that is, a sensation of *light* rather than of pressure or electricity. This suggested to him that we are not directly aware of the outside world, but instead only of the signals in the nervous system.⁸ In other words, when the nervous system tells you that something is “out there”—such as a light—that is what you will believe, irrespective of how the signals get there.

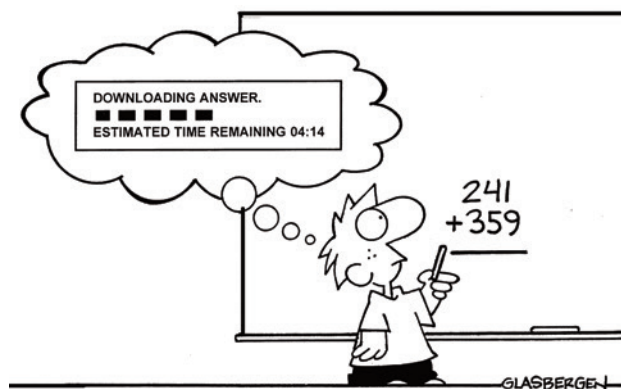
The stage had now been set for people to consider the physical brain as having a relationship with perception. In 1886, years after both Weber and Müller had died, an American named James McKeen Cattell published a paper entitled “The time taken up by cerebral operations.”⁹ The punch line of his paper was deceptively simple: how quickly you can react to a question depends on the type of thinking you have to do. If you simply have to respond that you’ve seen a flash or a bang, you can do so quite rapidly (190 milliseconds for flashes and 160 milliseconds for bangs). But if you have to make a choice (“tell me whether you saw a red flash or a green flash”), it takes some tens of milliseconds longer. And if you have to name what you just saw (“I saw a blue flash”), it takes longer still.

Cattell’s simple measurements drew the attention of almost no one on the planet, and yet they were the rumblings of a paradigm shift. With the dawning of the industrial age, intellectuals were thinking about *machines*. Just as people apply the computer metaphor now, the machine metaphor permeated popular thought then. By this point, the later part of the nineteenth century, advances in biology had comfortably attributed many aspects of behavior to the machinelike operations of the nervous system. Biologists knew that it took time for signals to be processed in the eyes, travel along the axons connecting them to the thalamus, then ride the nerve highways to the cortex, and finally become part of the pattern of processing throughout the brain.

Thinking, however, continued to be widely considered as

something different. It did not seem to arise from material processes, but instead fell under the special category of the mental (or, often, the spiritual). Cattell's approach confronted the thinking problem head-on. By leaving the stimuli the same but changing the task (*now make such-and-such type of decision*), he could measure how much longer it took for the decision to get made. That is, he could measure *thinking time*, and he proposed this as a straightforward way to establish a correspondence between the brain and the mind. He wrote that this sort of simple experiment brings "the strongest testimony we have to the complete parallelism of physical and mental phenomena; there is scarcely any doubt but that our determinations measure at once the rate of change in the brain and of change in consciousness."¹⁰

Within the nineteenth-century zeitgeist, the finding that thinking takes time stressed the pillars of the thinking-is-immaterial paradigm. It indicated that thinking, like other aspects of behavior, was not tremendous magic—but instead had a mechanical basis.



Could thinking be equated with the processing done by the nervous system? Could the mind be like a machine? Few people paid meaningful attention to this nascent idea; instead, most continued to intuit that their mental operations appeared immediately at their behest. But for one person, this simple idea changed everything.

ME, MYSELF, AND THE ICEBERG

At the same time that Charles Darwin was publishing his revolutionary book *The Origin of Species*, a three-year-old boy from Moravia was moving with his family to Vienna. This boy, Sigmund Freud, would grow up with a brand-new Darwinian worldview in which man was no different from any other life-form, and the scientific spotlight could be cast on the complex fabric of human behavior.

The young Freud went to medical school, drawn there more by scientific research than clinical application. He specialized in neurology and soon opened a private practice in the treatment of psychological disorders. By carefully examining his patients, Freud came to suspect that the varieties of human behavior were explicable only in terms of unseen mental processes, the machinery running things behind the scenes. Freud noticed that often with these patients there was nothing obvious in their conscious minds driving their behavior, and so, given the new, machinelike view of the brain, he concluded that there must be underlying causes that were hidden from access. In this new view, the mind was not simply equal to the conscious part we familiarly live with; rather it was like an iceberg, the majority of its mass hidden from sight.

This simple idea transformed psychiatry. Previously, aberrant mental processes were inexplicable unless one attributed them to weak will, demon possession, and so on. Freud insisted on seeking the cause in the physical brain. Because Freud lived many decades before modern brain technologies, his best approach was to gather data from the “outside” of the system: by talking to patients and trying to infer their brain states from their mental states. From this vantage, he paid close attention to the information contained in slips of the tongue, mistakes of the pen, behavioral patterns, and the content of dreams. All of these he hypothesized to be the product of hidden neural mechanisms, machinery to which the subject had no direct access. By examining the behaviors poking above the surface, Freud felt confident that he could get a sense of what was

lurking below.¹¹ The more he considered the sparkle from the iceberg's tip, the more he appreciated its depth—and how the hidden mass might explain something about people's thoughts, dreams, and urges.

Applying this concept, Freud's mentor and friend Josef Breuer developed what appeared to be a successful strategy for helping hysterical patients: ask them to talk, without inhibition, about the earliest occurrences of their symptoms.¹² Freud expanded the technique to other neuroses, and suggested that a patient's buried traumatic experiences could be the hidden basis of their phobias, hysterical paralysis, paranoias, and so on. These problems, he guessed, were hidden from the conscious mind. The solution was to draw them up to the level of consciousness so they could be directly confronted and wrung of their neurosis-causing power. This approach served as the basis for psychoanalysis for the next century.

While the popularity and details of psychoanalysis have changed quite a bit, Freud's basic idea provided the first exploration of the way in which hidden states of the brain participate in driving thought and behavior. Freud and Breuer jointly published their work in 1895, but Breuer grew increasingly disenchanted with Freud's emphasis on the sexual origins of unconscious thoughts, and eventually the two parted ways. Freud went on to publish his major exploration of the unconscious, *The Interpretation of Dreams*, in which he analyzed his own emotional crisis and the series of dreams triggered by his father's death. His self-analysis allowed him to reveal unexpected feelings about his father—for example, that his admiration was mixed with hate and shame. This sense of the vast presence below the surface led him to chew on the question of free will. He reasoned that if choices and decisions derive from hidden mental processes, then free choice is either an illusion or, at minimum, more tightly constrained than previously considered.

By the middle of the twentieth century, thinkers began to appreciate that we know ourselves very little. We are not at the center

of ourselves, but instead—like the Earth in the Milky Way, and the Milky Way in the universe—far out on a distant edge, hearing little of what is transpiring.

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Freud's intuition about the unconscious brain was spot-on, but he lived decades before the modern blossoming of neuroscience. We can now peer into the human cranium at many levels, from electrical spikes in single cells to patterns of activation that traverse the vast territories of the brain. Our modern technology has shaped and focused our picture of the inner cosmos, and in the following chapters we will travel together into its unexpected territories.

How is it possible to get angry at yourself: who, exactly, is mad at whom? Why do rocks appear to climb upward after you stare at a waterfall? Why did Supreme Court Justice William Douglas claim that he was able to play football and go hiking, when everyone could see that he was paralyzed after a stroke? Why was Topsy the elephant electrocuted by Thomas Edison in 1916? Why do people love to store their money in Christmas accounts that earn no interest? If the drunk Mel Gibson is an anti-Semite and the sober Mel Gibson is authentically apologetic, is there a real Mel Gibson? What do Ulysses and the subprime mortgage meltdown have in common? Why do strippers make more money at certain times of month? Why are people whose name begins with J more likely to marry other people whose name begins with J? Why are we so tempted to tell a secret? Are some marriage partners more likely to cheat? Why do patients on Parkinson's medications become compulsive gamblers? Why did Charles Whitman, a high-IQ bank teller and former Eagle Scout, suddenly decide to shoot forty-eight people from the University of Texas Tower in Austin?

What does all this have to do with the behind-the-scenes operations of the brain?

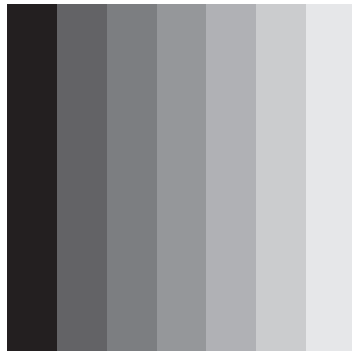
As we are about to see, everything.

2

The Testimony of the Senses: What Is Experience *Really* Like?

DECONSTRUCTING EXPERIENCE

One afternoon in the late 1800s, the physicist and philosopher Ernst Mach took a careful look at some uniformly colored strips of paper placed next to each other. Being interested in questions of perception, he was given pause by something: the strips did not look quite right. Something was amiss. He separated the strips, looked at them individually, and then put them back together. He finally realized what was going on: although each strip in isolation was uniform in color, when they were placed side by side each appeared to have a gradient of shading: slightly lighter on the left side, and slightly darker on the right. (To prove to yourself that each strip in the figure is in fact uniform in brightness, cover up all but one.)¹



Mach bands.

Now that you are aware of this illusion of “Mach bands,” you’ll notice it elsewhere—for example, at the corner where two walls meet, the lighting differences often make it appear that the paint is lighter or darker right next to the corner. Presumably, even though the perceptual fact was in front of you this entire time, you have missed it until now. In the same way, Renaissance painters noticed at some point that distant mountains appeared to be tinted a bit blue—and once this was called out, they began to paint them that way. But the entire history of art up to that point had missed it entirely, even though the data was unhidden in front of them. Why do we fail to perceive these obvious things? Are we really such poor observers of our own experiences?

Yes. We are astoundingly poor observers. And our introspection is useless on these issues: we believe we’re seeing the world just fine until it’s called to our attention that we’re not. We will go through a process of learning to observe our experience, just as Mach carefully observed the shading of the strips. What is our conscious experience *really* like, and what is it not like?

* * *

Intuition suggests that you open your eyes and voilà: there’s the world, with all its beautiful reds and golds, dogs and taxicabs, bustling cities and floriferous landscapes. Vision appears effortless and, with minor exceptions, accurate. There is little important difference, it might seem, between your eyes and a high-resolution digital video camera. For that matter, your ears seem like compact microphones that accurately record the sounds of the world, and your fingertips appear to detect the three-dimensional shape of objects in the outside world. What intuition suggests is dead wrong. So let’s see what’s really happening.

Consider what happens when you move your arm. Your brain depends on thousands of nerve fibers registering states of contraction and stretching—and yet you perceive no hint of that lightning storm of neural activity. You are simply aware that your limb

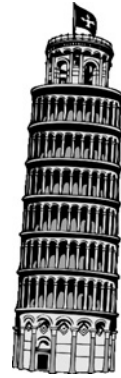
moved and that it is somewhere else now. Sir Charles Sherrington, an early neuroscience pioneer, spent some time fretting about this fact during the middle of the last century. He was awestruck by the lack of awareness about the vast mechanics under the surface. After all, despite his considerable expertise with nerves, muscles, and tendons, he noted that when he went to pick up a piece of paper, “I have no awareness of the muscles as such at all. . . . I execute the movement rightly and without difficulty.”² He reasoned that if he were not a neuroscientist it would not have occurred to him to suspect the existence of nerves, muscles, and tendons. This intrigued Sherrington, and he finally inferred that his experience of moving his arm was “a mental product. . . . derived from elements which are not experienced as such and yet . . . the mind uses them in producing the percept.” In other words, the storm of nerve and muscle activity is registered by the brain, but what is served up to your awareness is something quite different.

To understand this, let’s return to the framework of consciousness as a national newspaper. The job of a headline is to give a tightly compressed summary. In the same manner, consciousness is a way of projecting all the activity in your nervous system into a simpler form. The billions of specialized mechanisms operate below the radar—some collecting sensory data, some sending out motor programs, and the majority doing the main tasks of the neural workforce: combining information, making predictions about what is coming next, making decisions about what to do now. In the face of this complexity, consciousness gives you a summary that is useful for the larger picture, useful at the scale of apples and rivers and humans with whom you might be able to mate.

OPENING YOUR EYES

The act of “seeing” appears so natural that it is difficult to appreciate the vastly sophisticated machinery underlying the process. It may come as a surprise that about one-third of the human

brain is devoted to vision. The brain has to perform an enormous amount of work to unambiguously interpret the billions of photons streaming into the eyes. Strictly speaking, all visual scenes are ambiguous: for example, the image to the right can be caused by the Tower of Pisa at a distance of five hundred yards, or a toy model of the tower at arm's length: both cast the identical image on your eyes. Your brain goes through a good deal of trouble to disambiguate the information hitting your eyes by taking context into account, making assumptions,



and using tricks that we'll learn about in a moment. But all this doesn't happen effortlessly, as demonstrated by patients who surgically recover their eyesight after decades of blindness: they do not suddenly see the world, but instead must *learn* to see again.³ At first the world is a buzzing, jangling barrage of shapes and colors, and even when the optics of their eyes are perfectly functional, their brain must learn how to interpret the data coming in.

For those of us with a lifetime of sight, the best way to appreciate the fact that vision is a construction is by noticing how often our visual systems get it wrong. Visual illusions exist at the edges of what our system has evolved to handle, and as such they serve as a powerful window into the brain.⁴

There is some difficulty in rigorously defining "illusion," as there is a sense in which all of vision is an illusion. The resolution in your peripheral vision is roughly equivalent to looking through a frosted shower door, and yet you enjoy the illusion of seeing the periphery clearly. This is because everywhere you aim your central vision appears to be in sharp focus. To drive this point home, try this demonstration: have a friend hold a handful of colored markers or highlighters out to his side. Keep your gaze fixed on his nose, and now try to name the order of the colors in his hand. The results are surprising: even if you're able to report that there are some colors in your periphery, you won't be able to accurately

determine their order. Your peripheral vision is far worse than you would have ever intuited, because under typical circumstances your brain leverages the eye muscles to point your high-resolution central vision directly toward the things you're interested in. Wherever you cast your eyes appears to be in sharp focus, and therefore you assume the whole visual world is in focus.*

That's just the beginning. Consider the fact that we are not aware of the *boundaries* of our visual field. Stare at a point on the wall directly in front of you, stretch your arm out, and wiggle your fingers. Now move your hand slowly back toward your ear. At some point you can no longer see your fingers. Now move it forward again and you can see them. You're crossing the edge of your visual field. Again, because you can always aim your eyes wherever you're interested, you're normally not the least bit aware that there are boundaries beyond which you have no vision. It is interesting to consider that the majority of human beings live their whole lives unaware that they are only seeing a limited cone of vision at any moment.

As we dive further into vision, it becomes clear that your brain can serve up totally convincing perceptions if you simply put the right keys in the right locks. Take the perception of depth. Your two eyes are set a few inches apart, and as a result they receive slightly different images of the world. Demonstrate this to yourself by taking two photographs from a few inches apart, and then putting them side by side. Now cross your eyes so that the two photos merge into a third, and a picture will emerge *in depth*. You will genuinely experience the depth; you can't shake the perception. The impossible notion of depth arising from a flat image divulges the mechanical, automatic nature of the computations in the visual system: feed it the right inputs and it will construct a rich world for you.

One of the most pervasive mistakes is to believe that our visual system gives a faithful representation of what is "out there" in the same way that a movie camera would. Some simple demonstrations

*Consider the analogous question of knowing whether your refrigerator light is always on. You might erroneously conclude that it is, simply because it appears that way every time you sneak up to the refrigerator door and yank it open.

THE TESTIMONY OF THE SENSES



Cross your eyes: the two images feed your brain the illusory signal of depth.

can quickly disabuse you of this notion. In the figure below, two pictures are shown.

What is the difference between them? Difficult to tell, isn't it? In a dynamic version of this test, the two images are alternated



Change blindness.

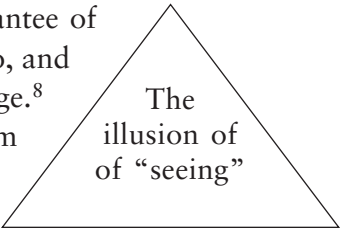
(say, each image shown for half a second, with a tenth of a second blank period in between). And it turns out we are blind to shockingly large changes in the scene. A large box might be present in

one photo and not the other, or a jeep, or an airplane engine—and the difference goes unseen. Our attention slowly crawls the scene, analyzing interesting landmarks until it finally detects what is changing.* Once the brain has latched onto the appropriate object, the change is easy to see—but this happens only after exhaustive inspection. This “change blindness” highlights the importance of attention: to see an object change, you must attend to it.⁵

You are not seeing the world in the rich detail that you implicitly believed you were; in fact, you are not aware of most of what hits your eyes. Imagine you’re watching a short film with a single actor in it. He is cooking an omelet. The camera cuts to a different angle as the actor continues his cooking. Surely you would notice if the actor changed into a different *person*, right? Two-thirds of observers don’t.⁶

In one astonishing demonstration of change blindness, random pedestrians in a courtyard were stopped by an experimenter and asked for directions. At some point, as the unsuspecting subject was in the middle of explaining the directions, workmen carrying a door walked rudely right between the two people. Unbeknownst to the subject, the experimenter was stealthily replaced by a confederate who had been hiding behind the door as it was carried: after the door passed, a new person was standing there. The majority of subjects continued giving directions without noticing that the person was not the same as the original one they were talking with.⁷ In other words, they were only encoding small amounts of the information hitting their eyes. The rest was assumption.

Neuroscientists weren’t the first to discover that placing your eyes on something is no guarantee of seeing it. Magicians figured this out long ago, and perfected ways of leveraging this knowledge.⁸ By directing your attention, magicians perform sleight of hand in full view. Their actions *should* give away the game—but they can



The
illusion of
of “seeing”

*If you haven’t spotted it yet, the change in the figure is the height of the wall behind the statue.

rest assured that your brain processes only small bits of the visual scene, not everything that hits your retinas.

This fact helps to explain the colossal number of traffic accidents in which drivers hit pedestrians in plain view, collide with cars directly in front of them, and even intersect unluckily with trains. In many of these cases, the eyes are in the right place, but the brain isn't seeing the stimuli. Vision is more than looking. This also explains why you probably missed the fact that the word "of" is printed twice in the triangle on the previous page.

The lessons here are simple, but they are not obvious, even to brain scientists. For decades, vision researchers barked up the wrong tree by trying to figure out how the visual brain reconstructed a full three-dimensional representation of the outside world. Only slowly did it become clear that the brain doesn't actually use a 3-D model—instead, it builds up something like a 2½-D *sketch* at best.⁹ The brain doesn't need a full model of the world because it merely needs to figure out, on the fly, where to look, and when.¹⁰ For example, your brain doesn't need to encode all the details of the coffee shop you're in; it only needs to know how and where to search when it wants something in particular. Your internal model has some general idea that you're in a coffee shop, that there are people to your left, a wall to your right, and that there are several items on the table. When your partner asks, "How many lumps of sugar are left?" your attentional systems interrogate the details of the bowl, assimilating new data into your internal model. Even though the sugar bowl has been in your visual field the entire time, there was no real detail there for your brain. It needed to do extra work to fill in the finer points of the picture.

Similarly, we often know one feature about a stimulus while simultaneously being unable to answer others. Say I were to ask you to look at the following and tell me what it is composed of: ||||| |||||. You would correctly tell me it is composed of vertical lines. If I were to ask you *how many* lines, however, you would be stuck for a while. You can see *that* there are lines, but you cannot tell me *how many* without considerable effort. You can know some things about

a scene without knowing other aspects of it, and you become aware of what you're missing only when you're asked the question.

What is the position of your tongue in your mouth? Once you are asked the question you can answer it—but presumably you were not aware of the answer until you asked yourself. The brain generally does not need to know most things; it merely knows how to go out and retrieve the data. It computes on a *need-to-know basis*. You do not continuously track the position of your tongue in consciousness, because that knowledge is useful only in rare circumstances.

In fact, we are not conscious of much of anything until we ask ourselves about it. What does your left shoe feel like on your foot right now? What pitch is the hum of the air conditioner in the background? As we saw with change blindness, we are unaware of most of what should be obvious to our senses; it is only after deploying our attentional resources onto small bits of the scene that we become aware of what we were missing. Before we engage our concentration, we are typically not aware that we are not aware of those details. So not only is our perception of the world a construction that does not accurately represent the outside, but we additionally have the false impression of a full, rich picture when in fact we see only what we need to know, and no more.

The manner in which the brain interrogates the world to gather more details was investigated in 1967 by the Russian psychologist Alfred Yarbus. He measured the exact locations that people were looking at by using an eye tracker, and asked his subjects to gaze at Ilya Repin's painting *An Unexpected Visitor* (next page).¹¹ The subjects' task was simple: examine the painting. Or, in a different condition, surmise what the people in the painting had been doing just before the "unexpected visitor" came in. Or answer a question about how wealthy the people were. Or their ages. Or how long the unexpected visitor had been away.

The results were remarkable. Depending on what was being asked, the eyes moved in totally different patterns, sampling the picture in a manner that was maximally informative for the question at

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Six records of eye movements from the same subject. Each record lasted three minutes. 1) Free examination. Before subsequent recordings, the subject was asked to: 2) estimate the material circumstances of the family; 3) give the ages of the people; 4) surmise what the family had been doing before the arrival of the “unexpected visitor”; 5) remember the clothes worn by the people; 6) estimate how long the “unexpected visitor” had been away from the family. From Yarbus, 1967.

hand. When asked about the ages of the people, the eyes went to the faces. When asked about their wealth, the focus danced around the clothes and material possessions.

Think about what this means: brains reach out into the world and actively *extract* the type of information they need. The brain does not need to see everything at once about *An Unexpected Visitor*, and it does not need to store everything internally; it only needs to know where to go to find the information. As your eyes interrogate the world, they are like agents on a mission, optimizing their strategy for the data. Even though they are “your” eyes, you have little idea what duty they’re on. Like a black ops mission, the eyes operate below the radar, too fast for your clunky consciousness to keep up with.

For a powerful illustration of the limits of introspection, consider the eye movements you are making right now while reading this book. Your eyes are jumping from spot to spot. To appreciate how rapid, deliberate, and precise these eye movements are, just observe someone else while they read. Yet we have no awareness of this active examination of the page. Instead it seems as though ideas simply flow into the head from a stable world.

* * *

Because vision appears so effortless, we are like fish challenged to understand water: since the fish has never experienced anything else, it is almost impossible for it to see or conceive of the water. But a bubble rising past the inquisitive fish can offer a critical clue. Like bubbles, visual illusions can call our attention to what we normally take for granted—and in this way they are critical tools for understanding the mechanisms running behind the scenes in the brain.

You’ve doubtless seen a drawing of a cube like the one to the right. This cube is an example of a “multistable” stimulus—that is, an image that flips back and forth between different perceptions. Pick what you perceive as the “front” face of the cube. Staring at the picture

