brain rules

12 Principles for Surviving and Thriving
at Work, Home and School

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Introduction

GO AHEAD AND MULTIPLY the number 8,388,628 x 2 in your head. Can you do it in a few seconds? There is a young man who can double that number *24 times* in the space of a few seconds. He gets it right every time. There is a boy who can tell you the precise time of day at any moment, even in his sleep. There is a girl who can correctly determine the exact dimensions of an object 20 feet away. There is a child who at age 6 drew such vivid and complex pictures, some people ranked her version of a galloping horse over one drawn by da Vinci. Yet none of these children have an IQ greater than 70.

The brain is an amazing thing.

Your brain may not be nearly so odd, but it is no less extraordinary. Easily the most sophisticated information-transfer system on Earth, your brain is fully capable of taking the little black squiggles in this book and deriving meaning from them. To accomplish this miracle, your brain sends jolts of electricity crackling through hundreds of miles of wires composed of brain cells so small that thousands of them could fit into the period at the end of this sentence. You accomplish all of this in less time than it takes you to blink. Indeed, you have just done it. What's equally incredible, given our intimate association with it, is this: Most of us have no idea how our brain works.

12 Brain Rules

My goal is to introduce you to 12 things we know about how the brain works. I call these Brain Rules. For each rule, I present the science, introduce you to the researchers behind it, and then offer ideas for how the rule might apply to our daily lives, especially at work and school. The brain is complex, and I am taking only slivers of information from each subject—not comprehensive but, I hope, accessible. Here is a sampling of the ideas you'll encounter:

• We are not used to sitting at a desk for eight hours a day. From an evolutionary perspective, our brains developed while we walked or ran as many as 12 miles a day. The brain still craves this experience. That's why exercise boosts brain power (Brain Rule #2) in sedentary populations like our own. Exercisers outperform couch potatoes in long-term memory, reasoning, attention, and problem-solving tasks.

• As you no doubt have noticed if you've ever sat through a typical PowerPoint presentation, people don't pay attention to boring things (Brain Rule #6). You've got seconds to grab someone's attention and only 10 minutes to keep it. At 9 minutes and 59 seconds, you must do something to regain attention and restart the clock—something emotional and relevant. Also, the brain needs a break. That's why I use stories in this book to make many of my points.

• Ever feel tired about three o'clock in the afternoon? That's because your brain really wants to take a nap. You might be more productive if you did. In one study, a 26-minute nap improved NASA pilots' performance by 34 percent. And whether you get enough rest at night affects your mental agility the next day. Sleep well, think well (Brain Rule #3).

• We'll meet a man who can remember everything he reads after seeing the words just once. Most of us do more forgetting than remembering, of course, and that's why we must repeat to remember (Brain Rule #7). When you understand the brain's rules for memory, you'll see why I want to destroy the notion of homework.

• We'll find out why the terrible twos only look like active rebellion but actually are a child's powerful urge to explore. Babies may not have a lot of knowledge about the world, but they know a whole lot about how to get it. We are powerful and natural explorers (Brain Rule #12). This never leaves us, despite the artificial environments we've built for ourselves.

The grump factor

I am a nice guy, but I am a grumpy scientist. For a study to appear in this book, it has to pass what some of my clients call MGF: the Medina Grump Factor. That means the supporting research for each of my points must first be published in a peer-reviewed journal and then successfully replicated. Many of the studies have been replicated dozens of times. (To stay as reader-friendly as possible, extensive references are not in this book but can be found at *www.brainrules.net/references*.)

No prescriptions

There's a great deal we don't know about the brain. I am a developmental molecular biologist specializing in psychiatric disorders. I have been a private consultant for most of my professional life, working on countless research projects beyond the lab bench. Over and over in my career, I have seen what a distance there is between a gene (one's DNA instructions) and a behavior (how a person actually acts). It's very hard to say with certainty that a specific behavior is caused by a specific gene, or that changing X behavior will produce Y result. Occasionally, I would run across articles and books that made startling claims based on "recent advances" in brain science about how we should teach people and do business. The Mozart Effect comes to mind: the popular idea that listening to classical music makes students better at math. Or the notion that analytical people are "left brain" people and creative people are "right brain" people, and each must be managed accordingly. Sometimes I would panic, wondering if the authors were reading some literature totally off my radar screen. I speak several dialects of brain science, and I knew nothing from those worlds capable of dictating best practices for education and business. In truth, if we ever fully understood how the human brain knew how to pick up a glass of water, it would represent a major achievement. There was no need for me to panic. Brain research still cannot without equivocation tell us how to become better teachers, parents, business leaders, or students. In addition to the ideas you'll find within each chapter, I end each chapter a few more potential ways to apply the research in our daily lives. But these are not prescriptions. They are hypotheses. If you try them, you will be doing your own little research project to see whether they work for you.

Back to the jungle

What we know about the brain comes from biologists who study brain tissues, experimental psychologists who study behavior, cognitive neuroscientists who study how the first relates to the second, and evolutionary biologists. Though we know precious little about how the brain works, our evolutionary history tells us this: The brain appears to be designed to (1) solve problems (2) related to surviving (3) in an unstable outdoor environment, and (4) to do so in nearly constant motion. I call this the brain's performance envelope.

Each subject in this book—exercise, sleep, stress, wiring, attention, memory, sensory integration, vision, music, gender, and exploration—relates to this performance envelope. We were in motion, getting lots of exercise. Environmental instability led to the extremely flexible way our brains are wired, allowing us to solve problems through exploration. To survive in the great outdoors, we needed to learn from our mistakes. That meant paying attention to certain things at the expense of others, and it meant creating memories in a particular way. Though we have been stuffing them into classrooms and cubicles for decades, our brains actually were built to survive in jungles and grasslands. We have not outgrown this.

Because we don't fully understand how our brains work, we do dumb things. We try to talk on our cell phones and drive at the same time, even though it is literally impossible for our brains to multitask when it comes to paying attention. We have created high-stress office environments, even though a stressed brain is significantly less productive than a non-stressed brain. Our schools are designed so that most real learning has to occur at home. Taken together, what do the studies in this book show? Mostly this: If you wanted to create an education environment that was directly opposed to what the brain was good at doing, you probably would design something like a classroom. If you wanted to create a business environment that was directly opposed to what the brain was good at doing, you probably would design something like a cubicle. And if you wanted to change things, you might have to tear down both and start over.

Blame it on the fact that brain scientists rarely have a conversation with teachers and business professionals, education majors and accountants, superintendents and CEOs. Unless you have the *Journal of Neuroscience* sitting on your coffee table, you're out of the loop.

This book is meant to get you into the loop.

Survival: Why your brain is so amazing

Brain Rule #1: The human brain evolved, too

When he was 4, my son Noah picked up a stick in our backyard and showed it to me. "Nice stick you have there, young fellow," I said. He replied earnestly, "That's not a stick. That's a sword! Stick 'em up!" I raised my hands to the air. We both laughed. As I went back into the house, I realized my son had just displayed virtually every unique thinking ability a human possesses—one that took several million years to manufacture. And he did so in less than two seconds. Heavy stuff for a 4-year-old. Other animals have powerful cognitive abilities, too, and yet there is something qualitatively different about the way humans think. How and why did our brains evolve this way?

A survival strategy

It all comes down to sex. Our bodies latched on to any genetic adaptation that helped us survive long enough to pass our genes on to the next generation. There's no bigger rule in biology than evolution through natural selection, and the brain is a biological tissue. So it too follows the rule of natural selection.

There are two ways to beat the cruelty of a harsh environment: You can become stronger or you can become smarter. We did the latter. It seems most improbable that such a physically weak species could take over the planet not by adding muscles to our skeletons but by adding neurons to our brains. But we did, and scientists have expended a great deal of effort trying to figure out how. I want to explore four major concepts that not only set the stage for all of the Brain Rules, but also explain how we came to conquer the world.

We can make things up

One trait really does separate us from the gorillas: the ability to use symbolic reasoning. When we see a five-sided geometric shape, we're not stuck perceiving it as a pentagon. We can just as easily perceive the US military headquarters. Or a Chrysler minivan. Our brains can behold a symbolic object as real by itself and yet, simultaneously, also representing something else. That's what my son was doing when he brandished his stick sword. Researcher Judy DeLoache calls it Dual Representational Theory. Stated formally, it describes our ability to attribute characteristics and meanings to things that don't actually possess them. Stated informally, we can make things up that aren't there. We are human because we can fantasize.

We are so good at dual representation, we combine symbols to derive layers of meaning. It gives us the capacity for language, and for writing down that language. It gives us the capacity to reason mathematically. It gives us the capacity for art. Combinations of circles and squares become geometry and Cubist paintings. Combinations of dots and squiggles become music and poetry. There is an unbroken intellectual line between symbolic reasoning and the ability to create culture. And no other creature is capable of doing it.

The all-important human trait of symbolic reasoning helped our species not only survive but thrive. Our evolutionary ancestors didn't have to keep falling into the same quicksand pit if they could tell others about it; even better if they learned to put up warning signs. With words, with language, we could extract a great deal of knowledge about our living situation without always having to experience its harsh lessons directly. It makes sense that once our species evolved to have symbolic reasoning, we kept it. So what was it about our environment that would give a survival advantage to those who could reason symbolically?

We adapted to variation itself

Most of what we know about the intellectual progress of our species is based on evidence of toolmaking. That's not necessarily the most accurate indicator, but it's the best we've got. For the first few million years, the record is not very impressive: We mostly just grabbed rocks and smashed them into things. Scientists, perhaps trying to salvage some of our dignity, called these stones "hand axes." A million years later, we still grabbed "hand axes," but we began to smash them into other rocks, making them more pointed. Now we had sharper rocks. It wasn't much, but it was enough to begin untethering ourselves from a sole reliance on our East African womb, and indeed any other ecological niche. Then things started to get interesting. We created fire and started cooking our food. Eventually, we migrated out of Africa in successive waves, our direct *Homo sapiens* ancestors making the journey as little as 100,000 years ago. Then, 40,000 years ago, something almost unbelievable happened. Our ancestors suddenly took up painting and sculpture, creating fine art and jewelry. This change was both abrupt and profound. Thirty-seven thousand years later, we were making pyramids. Five thousand years after that, rocket fuel.

Many scientists think our growth spurt can be explained by the onset of dual-representation ability. And many think our dual-representation ability—along with physical changes that precipitated it—can be explained by a nasty change in the weather.

Most of human prehistory occurred in junglelike climates: steamy, humid, and in dire need of air-conditioning. This was comfortably predictable. Then the climate changed. Ice cores taken from Greenland show that the climate staggers from being unbearably hot to being sadistically cold. As little as 100,000 years ago, you could be born in a nearly arctic environment but then, mere decades later, be taking off your loincloth to catch the golden rays of the grassland sun. Such instability was bound to have a powerful effect on any creature forced to endure it. Most could not. The rules for survival were changing, and a new class of creatures would start to fill the vacuum created as more and more of their roommates died out.

The change was enough to shake us out of our comfortable trees, but it wasn't violent enough to kill us when we landed. Landing was only the beginning of the hard work, however. Faced with grasslands rather than trees, we were rudely introduced to the idea of "flat." We quickly discovered that our new digs were already occupied. The locals had co-opted the food sources, and most of them were stronger and faster than we were. It is disconcerting to think that we started our evolutionary journey on an unfamiliar horizontal plane with the words “Eat me, I’m prey” taped to our evolutionary butts.

You might suspect that the odds against our survival were great. You would be right. The founding population of our direct ancestors is not thought to have been much larger than 2,000 individuals; some think the group was as small as a few hundred. How, then, did we go from such a wobbly, fragile minority population to a staggering tide of humanity seven billion strong and growing?

There is only one way, according to Richard Potts, director of the Human Origins Program at the Smithsonian’s National Museum of Natural History. We gave up on stability. We began not to care about consistency within a given habitat, because consistency wasn’t an option. We adapted to variation itself. Those unable to rapidly solve new problems or learn from mistakes didn’t survive long enough to pass on their genes. The net effect of this evolution was that rather than becoming stronger, we became smarter. It was a brilliant strategy. We went on to conquer other ecological niches in Africa. Then we took over the world.

Potts’s theory predicts some fairly simple things about human learning. It predicts interactions between two powerful features of the brain: a database in which to store a fund of knowledge, and the ability to improvise off that database. One allows us to know when we’ve made mistakes. The other allows us to learn from them. Both give us the ability to add new information under rapidly changing conditions. And both are relevant to the way we design classrooms and cubicles. We’ll uncover more about this database in the Memory chapter.

Bigger and bigger brains

Adapting to variation provides a context for symbolic reasoning, but it hardly explains our unique ability to invent calculus and write romance novels. After all, many animals create a database of knowledge, and many of them make tools, which they use creatively. Still, it is not as if chimpanzees write symphonies badly and we write them well. Chimps can't write them at all, and we can write ones that make people spend their life savings on subscriptions to the New York Philharmonic. There must have been something else in our evolutionary history that gave rise to unique human thinking.

One of the random genetic mutations that gave us an adaptive advantage involved walking upright on two legs. Because the trees were gone or going, we needed to travel increasingly long distances between food sources. Walking on two legs instead of four both freed up our hands and used fewer calories. It was energy-efficient. Our ancestral bodies used the energy surplus not to pump up our muscles but to pump up our minds.

This led to the masterpiece of evolution, the region that distinguishes humans from all other creatures. It is a specialized area of the frontal lobe, just behind the forehead, called the prefrontal cortex. What does the prefrontal cortex do? We got our first hints from a man named Phineas Gage, who suffered the most famous occupational injury in the history of brain science.

Gage was a popular foreman of a railroad construction crew. He was funny, clever, hardworking, and responsible, the kind of guy any father would be proud to call "son-in-law." On September 13, 1848, he set an explosives charge in the hole of a rock using a tamping iron, a three-foot rod about an inch in diameter. The charge blew the rod into Gage's head. It entered just under the eye and destroyed most of his prefrontal cortex. Miraculously, Gage survived. But he became tactless, impulsive, and profane. He left his family and wandered aimlessly from job to job. His friends said he was no longer Gage.

When damage occurs to a specific brain region, we know that any observed behavioral abnormality must in some way be linked to that region's function. I describe several such cases throughout the book for this reason. Gage's case was the first real evidence that the prefrontal cortex governs several uniquely human cognitive talents, called "executive functions": solving problems, maintaining attention, and inhibiting emotional impulses. In short, this region controls many of the behaviors that separate us from other animals (and from teenagers).

Three brains in one

The prefrontal cortex, however, is only the newest addition to the brain. Three brains are tucked inside your head, and parts of their structure took millions of years to design. Your most ancient neural structure is the brain stem, or "lizard brain." This rather insulting label reflects the fact that the brain stem functions the same way in you as in a Gila monster. The brain stem controls most of your body's housekeeping chores: breathing, heart rate, sleeping, waking. Lively as Las Vegas, these neurons are always active, keeping your brain buzzing along whether you're napping or wide awake.

Sitting atop your brain stem is your "mammalian brain." It appears in you the same way it does in many mammals, such as house cats, which is how it got its name. It has more to do with your animal survival than with your human potential. Most of its functions involve what some researchers call the "four Fs": fighting, feeding, fleeing, and … reproductive behavior. Several parts of the mammalian brain play a large role in the Brain Rules.

The amygdala allows you to feel rage. Or fear. Or pleasure. Or memories of past experiences of rage, fear, or pleasure. The amygdala is responsible for both the creation of emotions and the memories they generate. We'll explore the powerful effects of emotions, and how to harness them, in the Attention chapter.

The hippocampus converts your short-term memories into longer-term forms. The Memory chapter covers the surprising way that happens, and the key to remembering.

The thalamus is one of the most active, well-connected parts of the brain—a control tower for the senses. Sitting squarely in the center of your brain, it processes and routes signals sent from nearly every corner of your sensory universe. We'll return to this bizarre, complex process in the Sensory Integration chapter.

Folded atop all of this is your "human brain," a layer called the cortex. Unfolded, this layer would be about the size of a baby blanket, with a thickness ranging from that of blotting paper to that of heavy-duty cardboard. It is in deep electrical communication with the interior. Neurons spark to life, then suddenly blink off, then fire again. Complex circuits of electrical information crackle in coordinated, repeated patterns, racing to communicate their information along large neural highways that branch suddenly into thousands of exits. As we'll see in the Wiring chapter, these branches are different in every single one of us. Each region of the cortex is highly specialized, with sections for speech, for vision, for memory.

You wouldn't know all this just by looking at the brain. The cortex looks homogenous, somewhat like the shell of a walnut, which fooled anatomists for hundreds of years. Then World War I happened. It was the first major conflict where medical advances allowed large numbers of combatants to survive shrapnel injuries. Some of these injuries penetrated only to the periphery of the brain, destroying tiny regions of the cortex while leaving everything else intact. Enough soldiers were hurt that scientists could study in detail the injuries and the truly strange behaviors that resulted. Eventually, scientists were able to make a complete structure–function map of the brain. They were able to see that the brain had, over eons, become three.

Scientists found that as our brains evolved, our heads did, too: They were getting bigger all the time. But the pelvis—and birth canal—can be only so wide, which is bonkers if you are giving birth to children with larger and larger heads. A lot of mothers and babies died on the way to reaching an anatomical compromise. Human pregnancies are still remarkably risky without modern medical intervention. The solution? Give birth while the baby's head is small enough to fit through the birth canal. The problem? You create childhood. Most mammals reach adulthood within months. Our long childhood gave the brain time to finish its developmental programs outside the womb. It also created a creature vulnerable to predators for years and not reproductively fit for more than a decade. That's an eternity when you live in the great outdoors, as we did for eons.

But the trade-off was worth it. A child was fully capable of learning just about anything and, at least for the first few years, not good for doing much else. This created the concept not only of learner but, for adults, of teacher. Of course, it was no use having babies who took years to grow if the adults were eaten before they could finish their thoughtful parenting. We weaklings needed to outcompete the big boys on their home turf, leaving our new home safer for sex and babies. We decided on a strange strategy. We decided to try to get along with each other.

We cooperated: You scratch my back ...

Trying to fight off a woolly mammoth? Alone, and the fight might look like Bambi vs. Godzilla. Two or three of you together—coordinating behavior and establishing the concept of "teamwork"—and you present a formidable challenge. You can figure out how to compel the mammoth to tumble over a cliff, for one. There is ample evidence that this is exactly what we did.

This changes the rules of the game. We learned to cooperate, which means creating a shared goal that takes into account our allies' interests as well as our own. In order to understand our allies' interests, we must be able to understand others' motivations, including their reward and punishment systems. We need to know where their "itch" is. To do this, we constantly make predictions about other people's mental states. Say we hear news about a couple: *The husband died, and then the wife died.* Our minds start working to infer the mental state of the wife: *The husband died, and then the wife died of grief.*

We create a view, however brief, into the psychological interior of the wife. We have an impression of her mental state, perhaps even knowledge about her relationship with her husband. These inferences are the signature characteristic of something called

Theory of Mind. We activate it all the time. We try to see our entire world in terms of motivations, ascribing motivations to our pets and even to inanimate objects. The skill is useful for selecting a mate, for navigating the day-to-day issues surrounding living together, for parenting. Theory of Mind is something humans have like no other creature. It is as close to mind reading as we are likely to get.

This ability to peer inside somebody's mental life and make predictions takes a tremendous amount of intelligence and, not surprisingly, brain activity. Knowing where to find fruit in the jungle is cognitive child's play compared with predicting and manipulating other people within a group setting. Many researchers believe a direct line exists between the acquisition of this skill and our intellectual dominance of the planet.

When we try to predict another person's mental state, we have physically very little to go on. Signs do not appear above a person's head, flashing in bold letters his or her motivations. We are forced to detect something that is not physically obvious at all, such as fear, shame, greed, or loyalty. This talent is so automatic, we hardly know when we do it. We began doing it in every domain. Remember dual representation: the stick and the thing that the stick represents? Our intellectual prowess, from language to mathematics to art, may have come from the powerful need to predict our neighbor's psychological interiors. As I said, your brain is amazing.

Why did I want to spend time walking you through the brain's survival strategies? Because they aren't just part of our species' ancient history. They give us real insight into how humans acquire knowledge. We improvise off a database, thinking symbolically about our world. We are predisposed to social cooperation, which requires constantly reading other people. Along with the performance envelope, these concepts determine at the most fundamental level how our brains work.

Now that you've gotten the gist of things, let's dive into the details.

Brain Rule #1
The human brain evolved, too.

- The brain appears to be designed to (1) solve problems (2) related to surviving (3) in an unstable outdoor environment, and (4) to do so in nearly constant motion.

- We started with a "lizard brain" to keep us breathing, then added a brain like a cat's, and then topped those with the thin layer known as the cortex—the third, and powerful, "human" brain.

- We adapted to change itself, after we were forced from the trees to the savannah when climate swings disrupted our food supply.

- Going from four legs to two to walk on the savannah freed up energy to develop a complex brain.

- Symbolic reasoning is a uniquely human talent. It may have arisen from our need to understand one another's intentions and motivations. This allowed us to coordinate within a group, which is how we took over the Earth.

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what's in the full book

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