# Scan Thyself

In the summer of 1933, while swimming at the French vacation town of Saint Jean de Luz, the composer Maurice Ravel suffered a stroke. Although he had remained productive through a decade of mental agitation, battling depression, insomnia, and temporary amnesia, the stroke marked a turning point for Ravel. He first noticed its effects that day on his motor control, as he struggled to stay afloat in the water. But as the days passed, a more troubling long-term deficit became apparent. The stroke had destroyed his ability to create music.

Silencing one of the world's great composers was cruel enough, but the stroke had a more fiendish twist: Ravel could still appreciate music as vividly as before, and indeed his mind was filled with new musical ideas. But he had lost the ability to translate those ideas into a language that the external world could understand: either by writing or performing. In a sense, Ravel's stroke had left





him with the reverse of Beethoven's legendary deafness: he could take in music from the external world, but he couldn't give it back. "I've still got so much to say, so many ideas in my head," he would lament to his acquaintances. But those ideas were trapped inside the brain's black box, where they remained until his death in 1937.

Because Ravel's stroke also greatly impaired his mastery of written language—his biographer describes him taking eight days to compose a fifty-word letter to a friend—neurologists now believe that the composer had experienced a left-hemisphere stroke, damaging the linguistic centers in that part of the brain while leaving the more emotional right hemisphere intact. Music could still move Ravel after the stroke, but he couldn't translate that passion into symbols or physical movements; he could hear the totality of the musical sound, but couldn't break it down into its component parts.

Ravel's stroke reveals a typical pattern in the way the brain processes musical information: ordinary listeners generally rely on the right hemisphere when enjoying music, while musicians—particularly those capable of reading and writing sheet music—show additional activity in the left hemisphere. Ravel's musical aphasia supplies yet another example of the mind's fundamental modularity—even a seemingly unified task like composing music turns out to involve specialized areas of the brain: one hemisphere for dreaming up the melody and harmony, and one for transcribing them.

When we talk about musical genius, particularly among composers, what we're normally celebrating is a fusion of left- and right-hemisphere accomplishment: taking the intangible passions of music and turning them into something that can be recorded, transcribed, passed on to other musicians and other ears. Most of us ordinary listeners have to make do with the simpler, right-hemispheric pleasures of enjoying other people's music.

But if you think about our pleasure in music from a distance—

think about it the way we've thought about tickling or mindreading—it becomes a strange convention. Enjoying music seems simple compared to the notational skills of the great composers, but that simplicity is deceptive. Why do the raw wave forms of music have such control over our emotions? We feel passionate about our kids because that passion helps them survive in order to pass on their genes. But why do we feel passionate about a ballad or a guitar riff?

The more I understood about the brain, the clearer it seemed that the science could teach us immense amounts about behavior that triggers dedicated circuits in our heads: paying attention, falling in love, being afraid. These are all regions of experience that have unmistakable evolutionary significance, so it's no surprise that we should find specific architecture in the brain corresponding to each of them. But life is more than just instincts, and some of humanity's great pleasures come from experiences that seem, on the surface at least, to have a less direct connection to our evolutionary past. I know why I feel such a powerful bond with my children, but I have a hard time explaining why I still feel chills down my spine when I listen to Van Morrison's *Astral Weeks,* even though I must have played it a thousand times. What light could brain science shed on that mystery? Science has much to teach us about our instincts, but what about the intangibles?

One potential route involves changing the terms of the question. Instead of asking *why* music moves us, we can ask something else: what happens in our brains when music moves us? We may never know the evolutionary explanation for music's hold on the human psyche, and indeed there may be no direct explanation available, in that an ear for music may not be a trait that was directly selected for. (Music may be one of Stephen Jay Gould's famous "spandrels"—indirect by-products of other selected traits.) But we already know something about what actually happens in the brain





when we enjoy music. As Ravel's stroke demonstrates, most appreciation of music happens in the right hemisphere, which suggests that the intuitive opposition between language and music, between concrete categories and the more fluid associations of sound, have their origins in the brain's bilateral architecture.

We also know something about that most elusive and private of music experiences: the chill. Jaak Panksepp has been in pursuit of the neurochemistry of musical chills for more than a decade. His work—now supported by a number of other studies—makes a convincing case that the shiver of pleasure we experience while listening to our favorite music is the release of endogenous opioids, the same molecules implicated in social bonding, parental love, the "runner's high"—and, of course, in narcotic drugs like heroin and morphine. Panksepp has found that animals appear to have chill responses to music as well. In one widely cited study, he played dozens of records to chickens attached to equipment designed to record their shivers of pleasure. (The chickens turned out to have the strongest positive response to the late-era Pink Floyd record *The Final Cut.*) Here, again, a little knowledge of brain chemistry illuminates a new twist on our most familiar experiences: the pleasure of listening to music strangely connected to the pleasure of parenting, or of taking illegal drugs.

Imagine, then, taking Panksepp's experiment one step further: instead of a chicken's brain listening to Pink Floyd, let's peer into Ravel's brain—or one like it—as it dreams up a new composition in the years before his stroke. Thus far, most brain-imaging research has focused on normal brains and on brains that suffer from some kind of disability. But we also have the opportunity to scan brains that are unusual in the sense of being unusually gifted. What vista into the world of inspiration will this open up to us?

I don't know firsthand what moments of true musical inspiration feel like. For me, inspiration revolves around words and sentences, and not melody and harmony. I'm not imaging myself to be a literary Ravel, but stringing text into narratives and arguments has been the most fluid of my mental faculties for as long as I can remember. Could brain science have something useful to say about this talent? I wanted to know what was happening in my head when a new insight arrived, usually half formed and barely grasped: a vague connection between two ideas, a new way of introducing a troublesome chapter, a phrasing for a sentence. This faculty was less charged emotionally than many of the experiences I had explored in writing this book, but it was no less mysterious to me. For reasons probably both genetic and cultural, I am not much of a mystic, but these flashes of insight were the closest thing I had to the experience of mysticism. These sparks were the transcendence that Keats sought when he commanded us to "open wide the mind's cage'd doors." An idea shoots in front of my mind's eye seemingly out of nowhere. Where did it come from?

How extraordinary that we can even begin to answer this question! We can only speculate where new ideas come from in the sense of their evolutionary roots, and we don't really understand how the firing of neurons creates the rich subtleties of ideation. But we can determine, with split-second precision, the parts of the brain that are active in the creation of a new idea. We can map mental processes as ephemeral as having a hunch. On a fundamental level, we can tell *where* the hunch comes from. All it takes is a brave, nonclaustrophobic subject and a $2 million magnet.

I thought I was precisely that brave, nonclaustrophobic subject until they strapped my head down to the mechanical gurney, and I began sliding into a two-foot-wide tube, with only a mirror the size of a playing card supplying me with a glimpse of the outside world.

There's no better way to say it: I was having my head examined.





Mechanically speaking, the exam was being conducted by a five-ton GE Twin-Speed fMRI scanner. My guide through the world of advanced brain scanning was Joy Hirsch, director of Columbia University's Brain Imaging Group, who had graciously offered to help me in my pursuit: to see the brain, from the inside, as it comes up with a new idea.

In a sense, this pursuit had begun after my original experience with the Attention Trainer's neurofeedback device. A few sessions analyzing my beta levels during various attention-related tasks had made me curious about my brain's behavior during other activities. Writing itself has a strange hold over my psyche. I can be totally exhausted at the end of a long day, without the slightest urge to work, but if you sit me down in front of a computer and pull up a piece that I'm in the middle of writing, I'll invariably start tweaking the text—rearranging a phrase, inserting a few qualifications, punching up an opening line. It feels almost like a compulsion; I can't *not* tinker with the words. Before our son was born, I worried that it would be difficult to write with a toddler charging around the house, and indeed I found that many other tasks that required concentration—reading, interviewing someone on the phone—were in fact quite difficult with our son in the room with me. But writing was a breeze. When I'm truly locked in working on a passage, a 747 could be taking off in the room and I wouldn't notice.

So this was what I had come to Joy Hirsch to understand: when I'm in that zone, what is happening in my brain? I knew Joy was probably as well equipped as anyone on the planet to capture that mental activity; her center had just installed the state-of-the-art fMRI machine, and she had decades of experience interpreting brain images. The question was whether we could construct an experiment that would reveal this activity as clearly as possible. Would it even be possible for me to come up with an interesting idea with my head stuck inside a five-ton magnet?

A week or so before my appointment with the scanner, I suggested an experimental structure to Joy: we would begin with my reading a series of nonsense sentences, followed by my reading someone else's prose, and then I would read a passage of my own work—a passage from this book, in fact. In reading my own passage, I hoped to spur one of those imaginative leaps: something about the words would make me think of a new line to add, or a new way of phrasing the idea, or some other unpredictable insight. If all went well, the machine would take a snapshot of that idea forming in my head. Unlike neurofeedback technology, fMRI scans can capture subtle shifts of activity within a three-dimensional model of the brain by measuring levels of oxygenation in the blood of nerve cells. It is not a perfect view by any means—you have to have roughly 500,000 neurons active in an area for the scan to register them—but it is as close to pure vision of the mind's inner life as current technology allows us.

When I arrive for my session, Joy and I sit down in her office to review the terms of our experiment. She begins by telling me that she's replaced the initial "control" experiment of reading nonsense sentences with a standard visual test pattern of a flashing checkerboard.

"You can't really use nonsense as a control, because the brain goes nuclear with nonsense," she explains. "With normal activity—reading, or touching an object, or recognizing a face—you see very predictable activity in specific regions. It's like the brain is handing off the task to the appropriate area. But when you have noise, the whole brain seems to light up trying to make sense of it." There was something lovely in that image: the brain, faced with apparent chaos, leaning on all its resources looking for some hope of order in the mix.

Joy explains that each stage of the experiment will involve three sections of forty seconds each: rest, activity, rest. The scanner will





start up, and I'll do my best to think of nothing for forty seconds. Then the stimuli will begin—the flashing checkerboard or the text—and I'll process that for another forty seconds. And then I'll think of nothing again. Each 120-second stage will be repeated twice.

As Joy lays out the sequence, I start to worry that I won't have time to actually *think* while in the machine; I don't want to spend the whole forty seconds reading, particularly once we get to my own words. I want to have the words trigger some new idea or association in my head. So Joy agrees to make a last-minute addition: a final stage during which I'm shown a single sentence from my book and given the entire forty seconds to ruminate.

Then Joy walks me through the risks. "We're looking at your brain here. So there's a very small chance that we might see something in these scans, some abnormality."

I nod. "You mean a brain tumor."

"Sometimes when we do work with experimental subjects—people who come in to help with our research, and who don't have any symptoms—they say, 'If you see something in there, don't tell me.'"

"Hey, if you see something in there that you don't like," I smile ruefully, "by all means let me know."

Then she moves on to the dangers associated with the scanner itself. "It is a fundamentally safe procedure, noninvasive." I think of a news story from a few years back in which hospital staff had left a metal trash can in the room with an fMRI. When they began scanning a patient, the magnetic field triggered by the scanner being switched on turned the trash can into a lethal projectile that killed the guy instantaneously.

I choose not to bring this up.

Then her voice turns slightly more serious, which makes me think that whatever she's about to relate is something she deals with more regularly than tumors or flying trash cans. "You should also know that some people find being inside the scanner uncomfortable."

"Because it's so claustrophobic?"

"It's a small space, and the machine makes a lot of noise. Some people have a hard time in there. But you should know that I'll be there in the room with you, and if at any time you want to come out and catch your breath, we can do that very easily."

"I think I'll be all right," I say more or less honestly. I have my fair share of fears, but confined spaces isn't high on the list, and as long as no flying metal objects hurtle toward me in the first few seconds, I suspect I'll feel pretty safe in there.

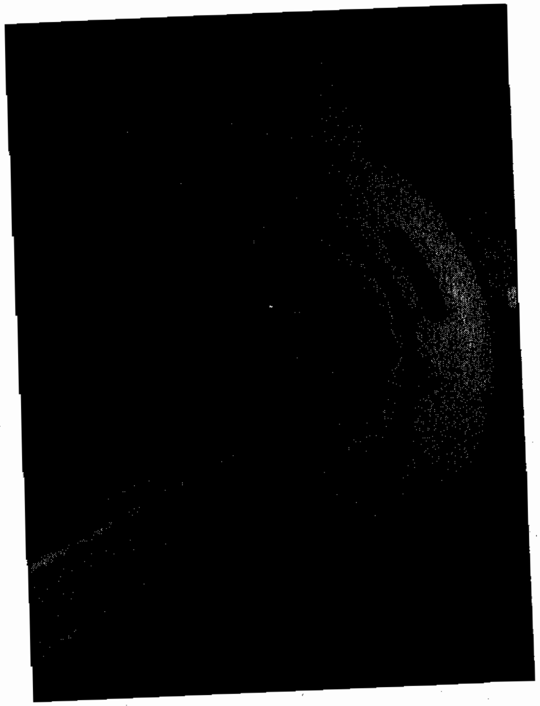
A minute or two later, we walk over to the fMRI room. The machine itself looks like an oversized clothes drier—about ten feet high with a huge GE logo embossed above the hollow tube at its center. I lie down on the mechanical gurney, and the technician gently tapes my forehead to the cradle at the end, hands me a pair of earplugs.

And then I'm in.

Being inside an fMRI machine is definitely more unpleasant than it looks to be from the outside. The space itself is astonishingly small, and the sense of being encased in a huge piece of machinery unsettles more than you think it will. For my experiment Joy and her team have placed a small mirror above my eyes that enables me to see a sliver of the world outside the tube. This sliver lets me read the text that they've projected onto a screen, but it also prompts a surge of nausea as I first enter the scanner. That queasiness, I know, is yet another side effect of two modules sending conflicting information: part of my brain reports that I've just been inserted in a cramped tunnel, while my eyes report a clear vista across the room. For a sec-







The author during his fMRI exam.

ond, I think, *I may actually have a problem with this. I may be one of those people who call out for a pit stop.*

And then I do what I normally do in a stressful situation, what I did on the biofeedback practitioner's couch. I make a joke—an internal joke that only I get to appreciate, but a joke nonetheless. I think to myself: *How is it that I ended up here? What strange series of life events led me to the point where I'm actually* asking *to be put into this insane device?* And after that, I'm all right. Uncomfortable, but all right.

The fMRI machine is capable of capturing two types of images: conventional MRIs that are higher resolution but don't show specific activity in the brain, and then lower-resolution "functional" images that show the brain actually thinking. (Functional MRI images work because active areas of the brain require an increase in oxygenated blood, which creates a small but detectable disturbance in a magnetic field.) We begin with a round of conventional images of my brain, during which time the machine rattles ominously around my head. Then we move on to our little experiment, starting with the checkerboard pattern.

You can easily tell when the fMRI is in its "functional" mode because it emits an uncomfortably loud, high-pitched, pulsing tone. (Hence the earplugs.) When you're actually inside the scanner, it sounds like a truck backing up into your head. For the first forty seconds of "rest," I find myself incapable of thinking about anything other than the excruciating noise. When the flashing checkerboard appears on the screen, it occurs to me that this is like attending some kind of demonic performance-art happening—a tiny, cramped space with strobing black-and-white images projected onto a screen, all accompanied by monotonous, piercing rhythmic tones.

But by the second iteration of the checkerboard stage, I start getting accustomed to the noise and the physical enclosure. I can see Joy smiling at me through the mirror, and the sound becomes more background noise than anything else. In fact, I feel comfortable enough that I start having difficulty shutting off my brain during the "rest" periods. First, I find myself thinking about ways that I could describe the setting, shaping the story of my fMRI experience while my head is still stuck inside the device. When I catch myself doing this, I smile in my dark tunnel. It occurs to me that this is one of those small examples of the brain's miraculous resilience and flexibility: you stuff your brain into a physical situation that should by all rights overwhelm it, *and* you tell it explicitly not to think of anything, and yet still it churns away in spite of everything. You couldn't imagine a more hostile environment for





free associating, but here my brain was riffing away, as though I were daydreaming in the shade of an oak tree.

Then I'm reading. Processing text turns out to be a bit of a strain, given the whole rearview mirror apparatus. Joy had selected a couple of passages from Nobel Laureate Eric Kandel's classic neuroscience textbook, while I had sent in a few paragraphs on Freud from an early draft of this book. I have to force myself to actually read the Kandel text, and not think about the bizarre setting. Of course, as anyone who ever suffered through fifth-grade mandatory summer reading assignments knows, when you have to actively remind yourself to pay attention to what you're reading, you're usually not reading very closely. Scanning the Kandel as it's projected onto the screen, I have to fight to keep up with the text. (If I'd been tested afterward, I'd wager that my retention would have been less than 50 percent.) It ends up being easier to focus on my own words, but there certainly isn't time to ruminate. As we finish that stage, I think to myself that I'm glad we added the rumination "bonus round."

I'm glad, but I'm also getting tired. I haven't moved my head more than a centimeter in around twenty-five minutes, and the space is starting to close in on me. When the first frozen slide of text arrives on the screen for the rumination stage, I feel like I've been caught off guard. "Shit!" I say to myself. "Now I have to think of something." For forty seconds of this $2 million machine's time, I think of absolutely nothing worthwhile. I think about trying to think about something. If there is a cognitive version of flailing, this is what I do for the first scan.

But when the second round—the last run of the entire experiment—arrives, I'm prepared. I decide to let my brain do what had come naturally to it throughout the experiment. I've already started down the road of describing the experience in the scanner—why not take this last round and actually start working out the language? And so when the text flashes up on the screen, notifying me that the forty-second rumination period has begun, a sentence starts to take form in my head. I am writing.

The words I string together in the fMRI are roughly the same words you encountered a few paragraphs ago describing the resilience of the brain in the most uncomfortable of situations. The general idea arrived a few minutes earlier, but the exact phrasing originates in that last session. The specific sentence, of course, is incidental; what makes it interesting is that Joy Hirsch and her fMRI are watching as it forms in my head, as my brain pulls the words out of the nothingness and makes them into something fixed—sturdy enough to remain intact until I sit down at my computer several days later to type them. For those last forty seconds, I have stumbled into my own small version of the zone—the one I have been wondering about since my first round with the Attention Trainers. And the cameras are rolling.

The results arrive in two stages. The first stage comes almost immediately: Joy gives a quick glance at the conventional MRI images of my brain, and announces that I have a healthy specimen. "Everything looks great," she says as she slaps the X-ray-like film onto a light board. "A textbook brain." I glow with pride for a second, and then think, *She probably tells this to all her experimental subjects.* Still, I find myself more pleased than I had expected to find out that I have no visible brain tumors. I think, *At least I've got that going for me.*

The second stage is where it gets interesting. A few days pass, and Joy sends an email to let me know that the results are in. "You're going to like this," she writes temptingly. The next afternoon I take the A train up to 168th Street, and Joy and I sit down at a conference table to spend some quality time with my brain.

Joy has assembled a collection of about forty color printouts, each displaying four images of my brain at work. The images are





overhead views, and each one is a "slice" of my brain, starting with the brain stem, at the very bottom, and ending with the tip of the cortex. For each stage of the experiment—there are four in total—the fMRI has captured twenty-five slices of my brain going about its business. That business takes the form of changes in blood flow to different regions; the scanner first looks at my brain during the "rest" periods, then during the "activity" period, and it records any salient differences between the two. These images let you see the areas that are relevant to a particular task, and shut out the background processing that the brain is always doing. My brain stem, for instance, was steadily plugging away maintaining my breathing pattern—along with many other mission-critical operations—but that area doesn't light up on the scan images because those patterns didn't change during the experiment.

Areas that do show noticeable changes appear on the images as a cluster of bright yellow pixels, fading out to orange and red at their peripheries. The images look strikingly like the Doppler radar images you see on the Weather Channel. (If you blur your eyes a little, you might think that yellow patch on the image was a thunderhead, not a brainstorm.) The image is projected over a grid with numbers running along each axis. The numbered grid and the slices create a three-dimensional system of coordinates, the latitude and longitude of neuromapping. The grid is made up of small cubes called "voxels," and each voxel has a specific address. (My amygdala is located at voxel 65, 70 of slice 13.) This lets you make easy comparisons between activity in scans of different brains, as well as look up areas in an artful, hand-drawn brain atlas that Joy consults at various times during our conversation.

Joy begins by laying down the twenty-five slices for stage one of our experiment, the dreaded checkerboard. The pattern of activity is immediately visible, even to my untutored eyes, mostly because there's literally nothing going on in 95 percent of my brain. Only a thin band wrapping around the back of my head, roughly at ear level, glows yellow.

"We know that the flashing checkerboard is a very salient stimulus for just the visual processing areas of the brain," she says. "And that's exactly what's happening here."

She points to the yellow band: "This part of the brain is all primary visual cortex. What's unique about this is that this activity doesn't get out of the occipital lobe—and *nothing* goes on in the frontal lobes. Nothing. This is just as exclusively visual as you can get." We both start to laugh. "Your brain is doing the minimal amount it has to do to sit there and look at that stupid checkerboard!"

Looking at those blank areas on my mental map reminds me of all the times that someone had gravely explained to me that we only use 10 percent of our brains, and then waxed rhapsodic about how smart we'd be if we could tap 100 percent. Of course we only use a small percentage of our brain at any given time—and it's a good thing, too! Your brain has dozens of dedicated tools, most of which aren't relevant to whatever it is you're focusing on right now. If your visual cortex keeps kicking into overdrive as you're trying to memorize a speech, the words won't stay in your head as readily. Only using 10 percent of your brain is a sign of *efficiency*, not underachievement. Arguing that we'd be better off with 100 percent is like raving about how great Shakespeare would have been if he'd managed to use all twenty-six letters in each of his words, instead of a small fraction of the alphabet.

Joy lays down the slices from stage two, when I read the mystery passages from Eric Kandel. The contrast with the first-stage images is startling: while the back of my head is lit up similarly, there's much more activity in the rest of the brain. Joy says, "You expect to see some visual processing, of course, because you're reading. But we'd also expected to see some higher-level functions."





She starts by pointing to a pair of yellow clusters, aligned symmetrically on the left and right sides of slice 12, about halfway up. "That's an area associated with eye movements—your eyes are darting back and forth reading, which they weren't doing in the checkerboard stage."

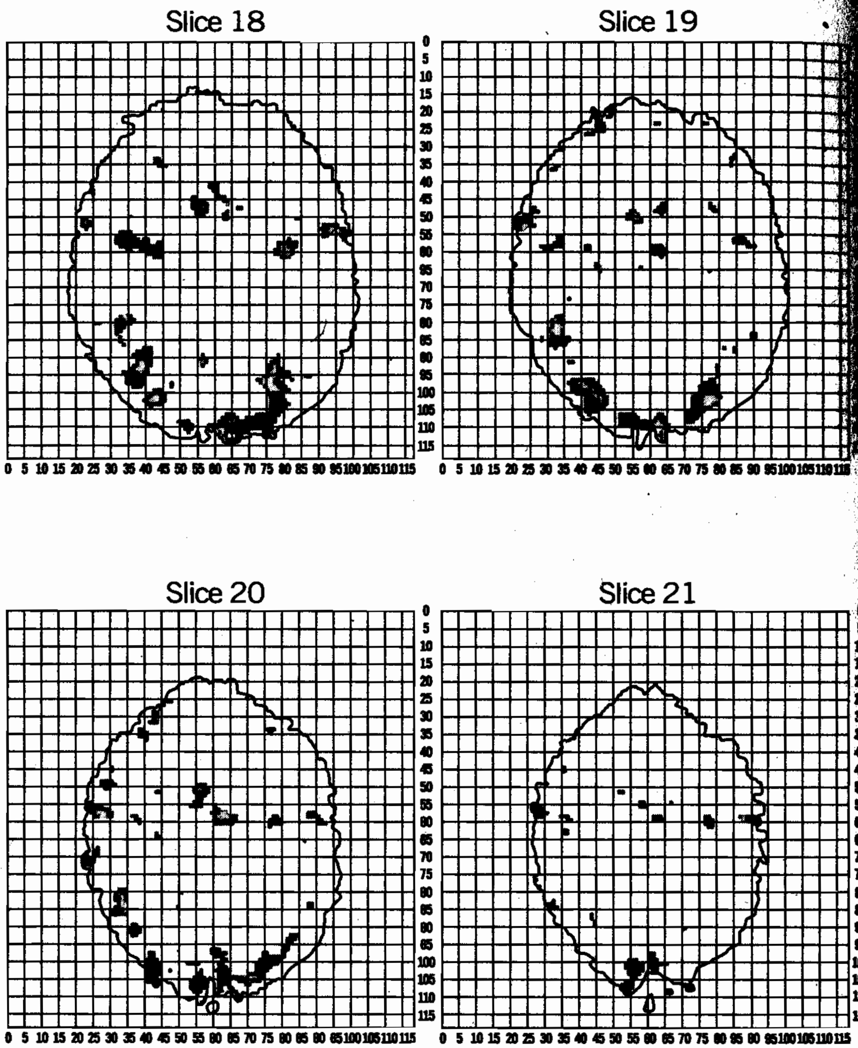
"Now, look at the difference here," she says, pointing at the slices one level up. There's quite a bit of activity, both in the middle of my brain and at the peripheries. "This is when we can see the higher-level processing. This is definitely language related—the dorsal part of Broca's area. There's just a lot more frontal activity all around." She puts down another set of slices. "This is Wernicke's area, loud and clear, whereas in the checkerboard phase, there's nothing there, just nothing. So your language areas, the visual system, the eye movement area—they're all participating in your reading of the text."

I need a little help in locating the major landmarks, but once I've got my bearings, the pattern is unmistakable. I feel a little like an autistic person learning to read facial expressions: it doesn't come naturally, but you can do it with enough practice. I turn to Joy and say, "So if you knew nothing about this experiment, and just looked at these images, would you be able to tell that this was someone reading?"

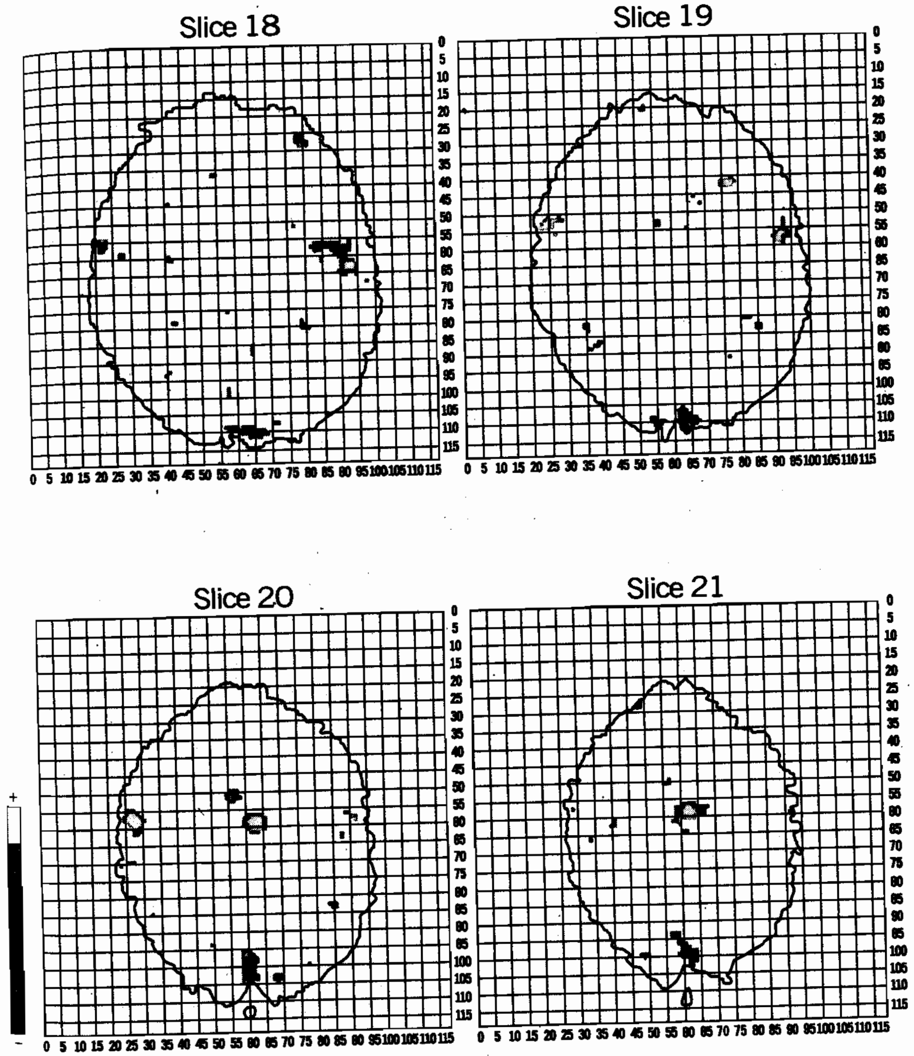
"Absolutely, absolutely. It's a textbook case." Then she smiles mischievously and starts to lay down the slices from stage three. "And this one—I'd say that this one was someone reading his favorite author."

We're looking at my brain reading my own words. At first glance, the images roughly parallel the pattern of the previous stage, but they're much hotter, as though the current has been turned up. The yellow clusters are larger and more pronounced. "Eric Kandel—Nobel laureate or not—can't hold a candle to this," Joy says, breaking into laughter.

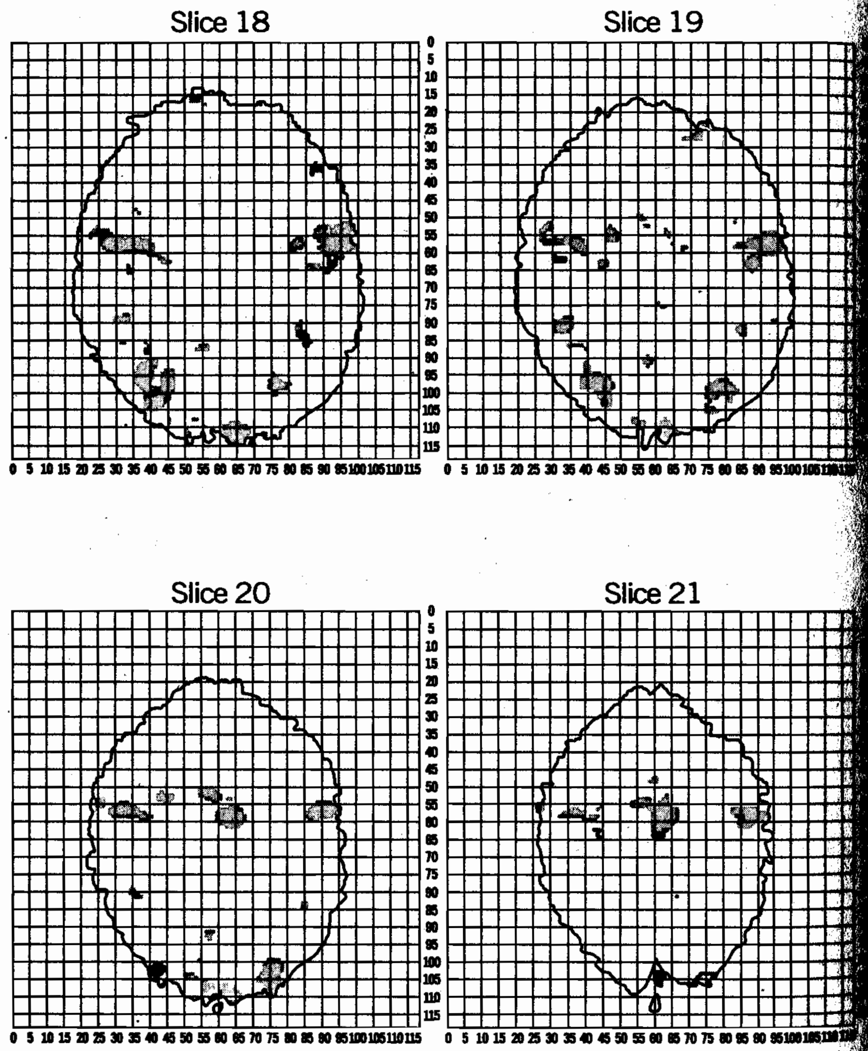
## THE AUTHOR'S FMRI BRAIN SCANS



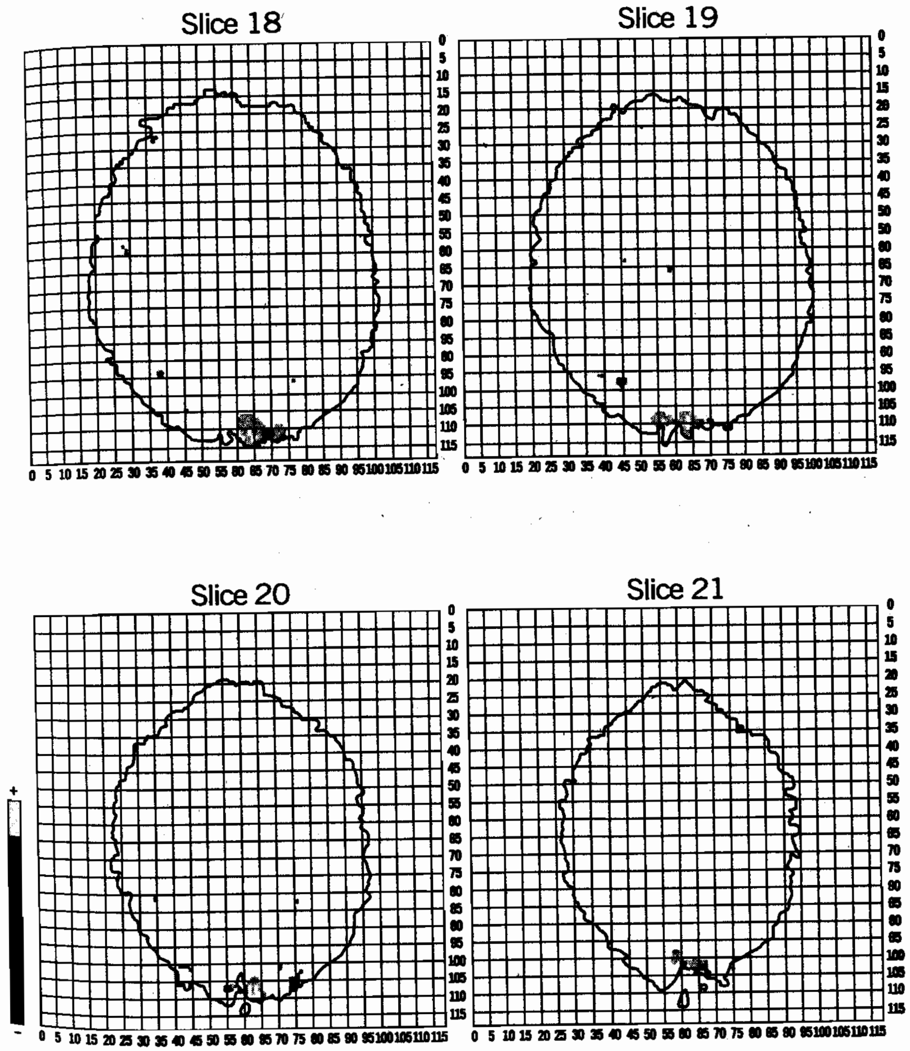

The Checkerboard Test




Reading




Failed Rumination




Successful Rumination

"Oh dear." I chuckle, slightly embarrassed at having dreamed up the experiment. "It was a vanity project from the beginning."

"Look at this," she says. "The same areas are working, but they're working much harder with your own words. It's amazing."

"I'm all aglow." I shake my head as I take in the images. I note that the hippocampus—the seat of memory—is now burning brightly, where it had been a dull red in the Kandel round. "So I've got more associations being triggered by these words because I wrote them."

"That's exactly right," Joy says. I think of all the times I've complained that it's hard to get a good feel for your own prose in its published form, because you've been there for all the first drafts and false starts, all the edits and tweaks and substitutions. All those alternative sentences crowd out your present-tense experience of reading. Now I can see that crowding directly, traced in those yellow voxels on the page.

I suppose it's possible to see this moment as the ultimate exercise in postmodern hall-of-mirrors self-reflection: you, dear reader, are reading a book describing a brain reading the book you're reading being read by a $2 million magnet. Who needs *The Matrix* when this is reality? Yet I think it's more accurate to see the activity as exactly the opposite: not an endless series of reflected reflections, but instead "dartlike and definite"—seeing the brain's actions directly, prying the mind open and taking a good look. I can see my hippocampus lighting up, filling my brain with associations and trace memories as I read my own words. That's reality, not illusion.

There's something in Joy Hirsch spreading out the images on the table that brings to mind a tarot card reader, but there's nothing mystical in her analysis. I find myself thinking, *This person I barely know has ventured inside my head in a way that no one has ever ventured before.* That's why the hall-of-mirrors interpretation feels





wrong to me. It's not an endless simulation I've entered into here, but rather something that feels authentic, even intimate.

Thus far all the images we've examined have been composite sketches: each stage included two runs, and so the images are a combined look at activity over the two of them. But with the rumination round, I had asked Joy to look at the two runs separately, because I had fared so poorly the first time around and because in the final run of the day, I had managed to get my brain exactly where I'd wanted it to be for my forty seconds in the spotlight.

The images from those two sessions do not disappoint. In the first run, small spots of activity are scattered across my brain, mostly in red voxels (suggesting less activity than the yellow). There's little shape or symmetry to the map; my brain looks cluttered. But in the second run, what jumps out at me immediately is how silent most of my brain appears. Only the language centers light up with any intensity, along with a sharp yellow rod at the center of my brain, extending up to the very top of my cranium. There's very little visual activity, and almost nothing from the eye-movement regions.

"There's a concept of efficiency that has emerged in the neuroimaging community in the last few years," Joy says. "It's basically that when there's a task that the brain is having difficulty doing, the pattern looks very distributed, like this here." She points to the cluttered image of run number 1. "This was not an efficient action—as opposed to here, where the specific tools of the brain are contributing in an efficient way to the task at hand."

"You really look like you got your act together here." She's pointing to that bright yellow dot on the upper images of run number 2. "Here's more evidence of that—look at this very focused medial frontal gyrus. This is one of the most distinguishing characteristics of this scan—this is a very high-level executive function of the brain, and you can see it running like a pole all the way down to the cingulate. I think that the medial frontal gyrus is important in coordinating different activities in the brain, reaching for the right tool at the right time. In this last scan, the entire structure—not just a part of it—is active." In Joy's phrasing, my language areas were perfectly "robust" during these inspired forty seconds, but they didn't turn out to be the most interesting element of the image. It was the overall orchestration, the clarity of the pattern, that stood out, the lack of mental clutter.

What had I been hoping to find? I thought about this on the subway ride home. In the crudest sense, I suppose I thought that my skill at stitching words together in my head might turn out to have its own modulelike presence in the scan: a distinct patch of neurons devoted to imagining sentences. If the brain is filled with all these modular tools, then somehow it seems logical that tasks you're good at should have some visible presence on the brain map. Sometimes this is the case: Einstein's brain had unusually large inferior parietal lobes, which we think gave him his extraordinary spatio-logical skills. (He famously solved problems as images in his head weeks before he could turn them into working equations.) Such a skill most likely would have shown up directly on an fMRI: a person gifted in spatial intelligence shows more activity in regions of the brain dedicated to spatial processing. I suspect that left frontal lobe of Ravel's brain would have lit up brilliantly had he been able to take an fMRI before his stroke.

But in my case, the scan revealed something quite different. (I'm no Einstein, as it turns out.) There was no special module. What caught Joy's eye in the final rumination scan was not a specific region, but the overall *pattern* of brain activity. The tools in the toolbox weren't particularly impressive, but the toolbox itself was well organized. In fact, the only specific region that seemed to be at all above average was the one responsible for coordinating activity





in other regions. My language areas were perfectly adequate, and my hippocampus seemed to kick in nicely when I was engaged with interesting text (or at least my own text). But perhaps the most telling thing about my brain map was what didn't show up on the images: when I was focused, there was almost no activity in areas that weren't related directly to the task at hand. Compare that to my episode of cognitive flailing in the first run of the rumination stage: on that scan, there's hardly a discernible pattern. It's mostly noise, and little signal.

I have no idea how replicable my fMRI results would be if I tried the exact experiment again, and it's unclear whether that pattern of organization—with its strong medial frontal gyrus and its many silent regions—holds true for my brain generally, or just for this little snapshot. But I suspect there is a larger truth nestled in that last fMRI image, one that has begun to change the way I think about people I know, much as learning about mindreading transformed the way I thought about people's social skills. I suspect that the world of talent is made up of two kinds of brains: some that have specific modules that are unusually good at their job, and some that are unusually good at keeping all the different modules organized. Both types of brains come across to us as talented, as intelligent, but I think the types are different enough that you can learn to recognize them if you know what to look for. We all know people who have dazzling skills: they can sit down at a piano and pick out a tune they heard last week; they can calculate interest rate payments in their head; they can actually understand quantum mechanics. But we also know people whose brains seem gifted in a different way: no stunning, off-the-chart skills, but a general competence and efficiency, with very little noise complicating their signal.

My dad used to say to me during my high school years: "You're not a rocket scientist, but you're smart and you've got a lot of talent." I used to bristle at the remark. (If I wanted to, maybe I *could* be a rocket scientist!) But now I think he was onto something. I've met rocket scientists—and astrophysicists, and programming wizards, and architectural geniuses—and I don't possess anything like what they've got mentally. I don't have their special gifts. But those fMRI images made me think that perhaps I have something else, a little less dazzling, but nothing to be ashamed of either. Maybe I have a well-*orchestrated* brain—with no world-famous soloists but a nice sound nonetheless. In a sense, this is what my dad had been trying to say, in slightly different language: I was talented in an orderly brain kind of way, not a supermodule kind of way.

It was only one experiment, but the machine had given me something that machines don't normally deal out: a hunch about myself, and maybe a larger hunch about people in general. I'd been dreaming for more than a year of capturing my brain as it came up with an idea, and thanks to Joy and her uncanny device, I'd managed to catch precisely that glimpse. The results were mesmerizing and remarkably legible, even to my untrained eyes. But they didn't provide unequivocal answers or magic bullets. They were more like clues.

Those fMRI scans of my brain were, technically speaking, the end of my journey inward—but they felt like a beginning. Seeing my brain come up with an idea had given me another, more interesting idea, one that still reverberates in my head as I write. Wouldn't it be nice to have a scan of *that*?



# CONCLUSION

## Mind Wide Open

"The deficiencies in our description would probably vanish if we were already in a position to replace the psychological terms with physiological or chemical ones. . . . We may expect [physiology and chemistry] to give the most surprising information and we cannot guess what answers it will return in a few dozen years of questions we have put to it. They may be of a kind that will blow away the whole of our artificial structure of hypothesis."

—Freud

All of us walk around with an operative theory of how the mind works. It's rarely a unified theory, of course: typically our models are cobbled together out of different disciplines and intellectual periods. We'll dabble in Eriksonian psychology and say that someone is having an "identity crisis;" we'll borrow from modern neuroscience and describe ourselves as "very right-brain"; we'll steal a page from the mystics and refer to the Jungian unconscious or the

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*Designed by Kyoko Watanabe*
Text set in Adobe Caslon

Manufactured in the United States of America

1 3 5 7 9 10 8 6 4 2

Library of Congress Cataloging-in-Publication Data
Johnson, Steven.
Mind wide open: your brain and the neuroscience of everyday life/Steven Johnson.
p. cm.
Includes bibliographical references and index.
1. Neurosciences. 2. Neuropsychology. 3. Self-perception. I. Title.
RC341.J648 2004
612.8'2—dc22
2003063308

ISBN 0-7432-4165-7
0-7432-4166-5 (Pbk)

Portions of this book first appeared in *Discover* magazine and *The Nation.*



*For my boys*