

## Journey to the Center of My Mind

Brain scans can locate the home of memory and the land of language. They may eventually help to map consciousness. By **STEPHEN S. HALL**

**A**t a few minutes after 4 on a Sunday afternoon in January, when most of New York was tuning in to the playoff game between the Jets and the Broncos, I had something else on my mind. More precisely, I had something around my mind, namely the 1.5-ton magnet of the magnetic resonance imaging (M.R.I.) machine at the Memorial Sloan-Kettering Cancer Center. I wasn't there for medical reasons; I was there to embark on an adventure. My journey would take me no farther than this laboratory on the Upper East Side of Manhattan, and yet I was going somewhere very few people have been.

Of all the frontiers that await exploration, perhaps no other is more intriguing than the terra incognita that lies between our ears. There, in a three-pound pudding of neurons and wiring, lie the keys to the kingdoms of memory, of thought, of desire, of fear, of the habits and skills that add up to who we each are. It is an especially daunting frontier because even after you have entered the realm of the brain, it's still necessary to locate a second, far more elusive boundary that separates the mere hardware of neurology from that elusive quality known as the mind, the "I" that hovers in the background of all conscious mental activity. I had hopes of getting a glimpse of that I -- my mind -- in the course of my travels.

My Virgil on this journey through the dark wood of cognition was Joy Hirsch, a voluble, cheerful scientist with dark bangs over her forehead and inch-long nails. Hirsch directs the [Functional Imaging Laboratory at Sloan-Kettering](#) and is a professor of neuroscience at the Weill Medical College of Cornell University. I'd become interested in her work several years ago when her group published a paper in *Nature* suggesting that you could tell whether a person learned a foreign language early or late in life by pinpointing the exact location of the speech center in the brain. When I proposed taking a tour of my own brain, Joy saw it as an opportunity to extend her research into some new areas.

The premise was simple. I would undergo a series of brain-imaging sessions using the technology of functional M.R.I. -- like diagnostic M.R.I., except that it also measures brain activity. These scans would, for the most part, be customized, almost autobiographical studies that would probe thoughts and emotions related to my personal history and work as a writer and editor. My journey, I understood, would be unscientific -- no study of one individual holds statistical significance. But even as a neural picaresque, it wasn't without value. We designed exercises with reasonable experimental controls and, whenever possible, in ways that might complement published studies. We set out to investigate, among other things, the use of figurative language, the neural residue of emotional memories, the seat of humor, the source of sentence composition and even the cognitive headwaters of storytelling.

Before setting out, I consulted several prominent brain scientists; Steven Pinker, the cognitive scientist at M.I.T., provided the most sage advice about the proper frame of mind for doing experiments in an



Embarking on his neural picaresque, the author enters the narrow bore of a M.R.I. machine. In three sessions, researchers will collect 226,000,000 data points about his brain.

Photograph by Raymond Meier

M.R.I. machine. "Focus is essential," he said. "You almost have to be a Zen master." Easier said than done.

## The Lay of the Land

**F**or the first session, Joy Hirsch set up 14 scans, designed to sketch out a rough map of the auditory, visual, touch, motor and language systems of my brain. "This is like a tour of the building before we start to talk to the individual departments," Joy said. This kind of mapping was pioneered by Hirsch's team at Sloan-Kettering to provide a guide for neurosurgeons so that they can avoid speech, hearing and other critical centers when removing brain tumors. (One condition for my participation was that patient scans always took precedence.)

As I lay flat on my back, about to enter the narrow bore of the scanner for the first time, Joy and a technician, Greg Nyman, sandwiched my head between cushions, placed a piece of tape across my forehead and slipped a plastic cowl over my head. "We're going to put you in," Joy announced as I felt myself slide about four feet into an aperture 23 inches wide and only 17 inches high. Staring up at a mirror above my head, I could look out of the tube, where the vista included two familiar shoes forming a nervous V in the air. Each "run," Joy explained, would last 144 seconds; the machine divided my brain into about 185,000 units, or voxels, and measured the activity in each every four seconds. The huge, room-size magnet allows the machine to detect subtle changes in blood flow in each voxel, changes that are believed to reflect levels of brain activity.

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Science is never quite as seamless as it appears in the pages of journals. The first few runs went fine -- a flashing checkerboard pattern excited my visual cortex, as planned, and Joy rubbed an ordinary five-and-dime pot-scrubber over my right hand, to stimulate the tactile (or somatosensory) part of my brain. I had great difficulty seeing and hearing, however. I couldn't wear my glasses inside the machine -- the powerful magnetic field would turn them into a ballistic missile. The prescription goggles on hand in the lab provided just enough visual acuity to turn an exercise where I named objects into a McGoo-ish misadventure. I mistook a tennis racket for a globe and a canoe for a comb. Later, straining to hear words through earphones, I could make out only a couple over the din of the machine, which sounds like the loudest, most emphatic busy signal imaginable. Again, I resorted to pure conjecture. At this rate, I began to fear we were using our precious M.R.I. time to pinpoint nothing more than the neural headquarters for Guesswork.

Finally, we made our first tentative sortie into the land of cognition. Joy knew I spoke Italian, and I was curious to see where the "Italian speech module" was located in my brain. I had learned the language in my mid-20's while living in Rome, but I thought there might be a chance I'd picked up a smattering of Italian as a child, since my maternal grandparents spoke it almost exclusively. It turns out that all languages learned early in life cohabit the same neural real estate, whereas a foreign language learned as an adult usually occupies a distinctly separate region. Would the conversations in Italian I had overheard as a child have left a neural residue?

To find out, Joy asked me to perform a task that formed the basis of the group's 1997 Nature paper. [[Consciousness Studies: From Stream to Flood](#)]. I had 10 seconds to tell a little story in my head in response to a series of visual prompts -- a picture showing either sunrise, noon or night. During the first run, I would think up a scenario in English; the second time, in Italian. The morning scene, for example, elicited the following: "I woke up around 8 o'clock, had a bite to eat, put on my coat and walked to the subway, which I took to work." All I can say in my literary defense is, you try being clever with a deadline of 10 seconds and 110-decibel honks in your ears about five times a second.

Lying stock still in a horizontal phone booth might not sound like much of a physical adventure, but after 50 minutes I felt exhausted by the effort of inactivity. You're supposed to keep your head as steady as a statue, and just as empty. But any active, imaginative intelligence is apt to daydream, worry, have idle thoughts -- all forms of mental static. Thoughts kept crashing through the artificial quietude of my empty head: "What's the Italian word for joke?" "Wonder how the Jets are doing?" "Man, is my mouth dry!" Theoretically, each of those errant thoughts has its latitude and longitude, its little magnetic wrinkle destined, perhaps, to show up in the raw data and fog this high-tech mirror in which I hoped to see something of myself.

### All Roads Lead to ... Broca's Area

**W**hen I met with Joy to go over the results from the first session, we sat at a round table in her office, with 21 cross-sectional slices of my brain up on the light box, a brain atlas open on the table and small printouts of each cross-section in front of her, marked by yellow Post-it arrows pointing to the predominant landmarks of my neural anatomy. She had carefully compared the lay of my brain to a standard atlas and, slice by slice, walked me through the basic landscape. "I love looking at brains," she confided at one point. "They're very beautiful, very intimate." Everything looked normal. "This is a beautiful, textbook brain," she said with obvious enthusiasm. But I almost didn't hear her. I was mesmerized by the beauty of this hidden landscape.

Now that I was on a guided tour of my own brain, I began to appreciate just how precise the convoluted geography of the brain actually is. Like a lot of laypeople, I thought the whorls and folds on the surface layer of the brain, known as the cortex, varied by individual like so many fingerprints. In fact, the patterns are basically the same in everyone. As I could see in Joy's atlas, each bulge (or gyrus) and each crevice (or sulcus) is as precisely plotted as any topographic map. All the cognitive action happens in those whorls; everything else is scaffolding, underground cable, antique structures handed down by evolution from reptile and early mammalian brains.

The first departments we checked were the somatosensory and motor regions. The touch of the pot-scrubber caused a small section of the post-central gyrus on the left side to light up, as expected, while the finger-tapping exercise caused a herd of neurons just across the deep neural ravine from the tactile center to become active.

"This is very typical," Joy said. "In fact, it's particularly nice. Some brains have a little bit less specific activity. One of the nice things about the activity patterns in your brain is that they are very localized. Your brain just goes and gets the job done. It doesn't waste a lot of energy going other places."

I'd been concerned about my inability to see and hear stimuli during the first session, but those difficulties actually made the results more interesting. When I was straining to make out images during the object-naming task, my visual cortex looked like the wall of napalm scene in "Apocalypse Now." "I'll tell you, this little brain was working mighty hard to get that information," Joy said with a laugh. The same evidence of effort showed up in the auditory map -- the place in the midbrain that "listens," called the transverse temporal gyrus, was screaming in technicolor, even though I could only make out one or two words.

Finally, we looked at my basic language centers. Language, of course, is normally located on the dominant side of the brain, which in right-handers like me is on the left side. When I spoke to myself in



The lines show the location of the 21 slices of neural territory measured. The scan at far left is slice No. 12.

English, therefore, a small patch of cortex on the left side lighted up. This is known as Broca's area, after the French pathologist who first identified it.

The data from the Italian-speaking exercise unfortunately were ambiguous. The image was filled with green blotches that signified movement. As anyone who watched Roberto Benigni at the Academy Awards knows, Italian is a particularly kinetic language. "The only time you moved your head the whole time was when you were speaking Italian!" Joy cried, explaining why she couldn't definitively say if my Italian was learned early or late. With prodding, she pointed out a tiny gap between the areas that lighted up when I spoke to myself in English and Italian. "If I had to call it," she said, "you have Italian sitting above the English, and both of them are pinned together here in Broca's area." That tiny gap, about five millimeters, suggested that I'd learned Italian as an adult, not as a child.

If there was a lesson from this first expedition, it was this: in terms of neural architecture, we all live in Levittown. Every brain is pretty much like the next. What makes each unique is how we decorate them, as it were, with experience and memory and habits and skills. Staring at these voluptuous, serpentine folds of cortex, I was struck by the strange commingling of inert anatomy and transcendent human qualities. Buried in those headlands and crevices, I knew, were mental images of grandparents no longer alive, of my mother trying to explain death to me for the first time, the sound of loved ones' voices, my father encouraging me as we played catch, of Roberto Clemente whirling and throwing a baseball, as well as the state capital of Vermont, the square root of 81 and the narrative line of three books I've written. The vastness and steadfastness of those memories, all nestled and synaptically etched in this bland gray and squishy landscape, was a miracle impossible to capture on film and perhaps beyond the grasp of our very modest experiments.

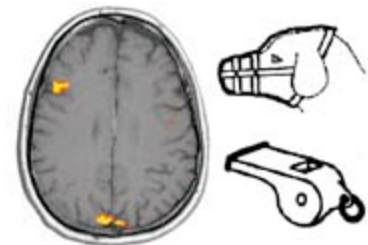
But we could try. We decided to devote the next session to exploring things that might be unique to me as a writer and as a person. We would search for the headwaters of storytelling, and we'd try to see if the brain reacted differently when it encountered family and friends as opposed to the faces and voices of strangers.

### To the Source of the Narrative

Joy and Diana Moreno, an Argentine graduate student in her lab, devised a plan to watch my brain in action as it invented a story. They would provide me with a set of narrative prompts -- either a sequence of simple images (like a dog or a tree) or, using a different sensory route to the same destination, a sequence of distinctive sound effects (a honking horn, a crying baby). While the M.R.I. was blasting away, I'd ad-lib a running story in my head (see box).

The results were fascinating. We saw the visual cortex light up as expected. But we also saw many small, discrete precincts of the frontal lobe activated on the right side of the brain, with particularly intense activity in an area called the inferior frontal gyrus -- what might be called the storytelling area. "This is not a subtle effect, Steve," Joy pointed out. "In this business, this is big." It seemed to cover at least 1.5 cubic centimeters -- about the size of a sugar cube. I asked her what might account for its size, and she replied that it could be a combination of things: a natural predisposition to use the right side of my brain (nature) and probably my frequent use of it (nurture) in the course of a lifetime.

There were other areas involved; they formed a network, actually. But Joy seemed particularly taken with the notion that the brain parceled out two related capabilities -- one to create stories and the other to articulate them in speech -- in essentially the same place in the two hemispheres, for my



In one of the storytelling exercises, I was shown this sequence of 10 images and asked to create a running narrative that incorporated the pictures. This is the story I told myself in the allotted 44 seconds.



storytelling area was the mirror image of the site on the left, dominant side of the brain that controls speech.

Next we compared familiar voices and faces to unfamiliar voices and faces. When I had suggested the idea of looking at familiar faces while in the machine, I thought it might serve as a back road to memory and feeling; the difference between the perception of an unknown and known face should be the neural residue of recognition and familiarity. Once again, we were in for some surprises.

As the M.R.I. beeped around my head, I was shown a series of 52 photographs over the course of four runs, 13 per run. During the first two runs, none of the faces were familiar -- or, at least, they weren't supposed to be. One picture happened to be a spitting image of the girl -- I'll call her D. -- I had a crush on in high school and whom I'd asked, unsuccessfully, to the senior prom. As I processed this image, I experienced what felt like an Etna of neural activity somewhere in my cranium.

During the next two runs, I was shown only familiar faces -- indeed, painfully familiar in the case of images of myself as Sullen Adolescent and Alienated Hirsute Expatriate. My wife, Mindy, had sent Joy's lab photographs of practically everybody I knew: my parents, Mindy giving birth to our son, my nephews, the college friend I bummed around with in Europe, old family friends, even my old landlady from Rome, as well as six photos of my younger self, including a high-school graduation picture of me looking so clueless that I wouldn't have gone to the prom with me.

When we reviewed the brain scans a few days later, I had the thrill of witnessing a unique feature of the physical world for the first time. During the familiar-faces experiment, we saw activity in the visual cortex; no surprise there. We saw activity in the hippocampus. No surprise there, either; the hippocampus, a structure deep in the interior of the brain, is thought to be involved in the storage of long-term memory. "Your whole hippocampus is screaming!" Joy said. We also saw activity in a structure adjacent to the hippocampus known as the fusiform gyrus; this, too, was not a surprise, at least not to Joy. Recent research on face recognition has identified this as the key area in the brain for the specialized task of perceiving faces. What was a surprise was that the most excited sector in my brain as it viewed familiar faces was, once again, the "storytelling area."

Next, we performed the same exercise using familiar voices: relatives and friends provided the lab with taped monologues addressed to me. Unfortunately, I had the same difficulty making out the voices as in the earlier session; the only voice I could identify unambiguously was that of my wife. I guessed -- correctly, as it turns out -- that other voices belonged to my father, mother and daughter, although I didn't learn until later what they had actually said. My father recalled going to the 1966 All-Star game in St. Louis and meeting the Cub infielder Ron Santo on the plane home. My mother invoked memories of what she called the "friendly persuader" of my mischievous childhood (the wooden spoon). And my 3-year-old daughter, Micaela, had chattered, "Testing, one-two-three, Daddy, I love you, testing one-two-three." I didn't hear any of it.

But, remarkably, my brain apparently did. The scans showed the exact same far-flung network of parts fired up as when I was looking at familiar pictures -- including the storytelling region in my right brain. It was almost as if I subconsciously filtered out the background noise and heard what I needed to hear. And not only that, simply hearing familiar voices activated the visual cortex, as if I mentally pictured the people whose voices I heard.

Joy used that all-purpose, noncommittal, scientifically discreet word to describe this effect: interesting. Exercising the layperson's right to speculate, I was immediately taken by a literary notion: the role of narrative in memory. What the data seemed to suggest to me was that part of what makes a face or a

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voice familiar to us is that the brain attaches it to a narrative. Perhaps we "tag" people with narratives to help us remember them. The image or voice (and perhaps even the taste, touch or smell) of a familiar person summons up from our memories the story we've woven them into. That madeleine of Marcel Proust's seems less like a literary conceit and more like a brilliant scientific insight -- but then Proust understood at least as much about memory as any modern neuroscientist.

## The Land of Metaphor

**T**o map the creation of sentences in my brain, Joy showed me a series of words -- highway, dawn, border -- and asked me to use them in the most elaborate sentences I could think of, all in 10 seconds. One that stuck in my mind was, "The border between here and there is uncertain, and moving further into the future even as we speak."

Joy was particularly amused when she showed me the results of this exercise. The areas of activity were small, relatively discrete and, unlike virtually all of the other creative tasks I performed, well represented on the left as well as the right side of the brain, indicating, she said, excellent mental economy.

I reverted to my right-hemisphere bias on two other tasks: creating metaphors and synonyms. I suppose there might be something socially redeeming about spitting out a metaphor on cue, every four seconds, but after shoveling out 10 examples of figurative language in 40 seconds, it began to feel like an aerobic activity. The cues, once again, were simple illustrations: a globe, a wreath, a canoe, a snail, a tennis racket, a seahorse and so on. Considering some of my responses -- "Up the creek without a paddle" and "You've got quite a racket going on," to name two -- I worried that we'd overshot Metaphor Mountain on the map and landed in the Slough of Cliche.

**Preposterous as it may seem, I can imagine a day in the distant future when the M.R.I. machine replaces the couch, when the therapist uses words or odors or pictures to excite and pinpoint circuitry and then the neuroanatomist translates the images into explanations of behavior.**

Not so. During this task -- and to a great degree, during the Great Thesauric Expedition (as I now call the synonym task) -- the right side of my brain lighted up like a neon sign on a cheap diner. Almost all the usual suspects were on display: parts of the visual cortex, the language area, that interesting storytelling area in the inferior frontal gyrus and a spot toward the top of the brain, the medial frontal gyrus, that Joy believed was organizing and coordinating high-level activity on a number of tasks. With Joy's help, I was beginning to recognize a network I seemed to use over and over again.

As we reviewed the results, it occurred to me that we had begun to exhaust the usefulness of the geographic metaphor -- and perhaps that was the real point of the entire exercise. The more complex the task, the more dispersed the brain's activity. The pattern in the scans stopped looking like a landscape with a few isolated peaks and more like a circuit with an extravagant number of relay points.

The potential link between circuitry and consciousness became especially clear when we went looking for the seat of humor. Joy showed me Gary Larson cartoons, first with neutral, unfunny captions and then with their proper punch lines. Perhaps because of the circumstances, one cartoon in particular had me struggling to suppress a laugh. It showed a group of doctors in the midst of brain surgery. The neutral caption read, "Operating Room"; the Larson caption had one of the surgeons exclaiming: "Wow! His brain still uses vacuum tubes!"

In response to this and other cartoons, my brain looked like those aerial shots of Southern California during brush-fire season: there were little embers of neural activity all over. The hippocampus lighted up, suggesting the involvement of memory; the

thalamus on the right side became active (the first time we'd seen that in any of our experiments), suggesting sensory processing, and we even detected a little activity in the sensorimotor cortex, which normally controls physical movement. Joy immediately thought "smile," and I thought "laugh." Like a Chopin impromptu, my "humor network" hit a great many notes, high in the brain and low, and did so with lightning rapidity: visual processing, language processing, memory, the perception of a cognitive disjunction, and all of it seemingly wired to trip a laugh instantaneously. Moreover, this network began to suggest something more complex than mere cognition -- something like consciousness, for humor is very personal, turning as it does on such idiosyncratic traits as one's sense of irony, cognitive dissonance and Schadenfreude. The network we were seeing, with its unique linkages, represented my sense of humor.

### **There Is No Center There**

**A**s I look at my brain again, slice by slice, holding the film up to a window in my study, I am struck once more with the everyday wonder of the landscape -- the shadowy lines of sulci running like streams to nowhere from the interior of the cerebrum, the peninsular gyri, each plump with purpose and secrets, and, like a river running through it all, the midline separating right hemisphere from left. And more than ever, I realize that the organizing metaphor for this expedition -- a journey to the center of my mind -- has been misleading. As task after task demonstrated, there is no center of activity, only way stations in a circuit, winking at each other in milliseconds, churning in some mysterious neural communion. And the notion of mind? We didn't make much progress penetrating that mystery. Perhaps it's nothing more than the heat given off by our personalized circuits, everywhere and yet nowhere.

If, as Joseph Conrad once said, the most interesting places are the empty spaces on a map, the prefrontal cortex must be an especially fascinating place for brain scientists. We were puzzled by the general dearth of activity in my frontal lobe; although it is supposed to be the real crucible of human thought, none of our exercises seemed to tickle it into much activity. Indeed, there were many questions I wished to ask that we couldn't approach for reasons of practicality or time, or an inability to even formulate a workable experimental question. I was interested, for example, in exploring skills more particular to an editor than a writer, like fixing ungrammatical sentences. I would have liked to probe emotions more intently, especially things we feel every day like anger and insecurity and sexual arousal, but it turns out they are exceedingly difficult to test in a meaningful way. I would have also liked to see what the brain looked like as it wrestled with a moral dilemma.

Brain scientists would like to know the answers to many of those questions, too. But as Joy, whose great-grandmother traveled the Oregon Trail, likes to point out, we're still in the "covered wagon" phase of mapping brain function. "When the real pioneers started their journey, they had no shortage of ideas about what Oregon was going to look like," she said. "And similarly, we have no shortage of ideas about mind and consciousness, even though we really haven't gone very far into the frontier." Even a modest journey like mine, however, hints at the territory ahead. "We have been able to observe several of the interconnected systems in your brain and perhaps have glimpsed some of your consciousness at work, even if it was only a snapshot of a brief instant of your life."

In our age-old struggle to understand the mind, we have always been empowered -- yet oddly constrained -- by the vocabulary of the moment, be it the voices of the gods in ancient myth, buried conflicts in the idiom of Freudian analysis or associative memories in Proustian terms. But as psychology and neuroscience begin to converge, brain imaging may actually provide a new, visual vocabulary with which to rethink, and perhaps reconcile, some of these older ideas of mind. A common thread of both the Freudian and Proustian worldviews is the associative quality of recollection -- the odd word or sight that connects to a deeper trauma, the odor that connects to a more extensive memory. Association requires connections, and as I saw, a brain scan of humor, for example, can actually depict a rich skein of associations in a diagram of neural connections. Preposterous as it may seem, I can imagine a day in the distant future when the M.R.I. replaces the couch, when the therapist uses words or odors or pictures to excite and pinpoint circuitry and then the neuroanatomist translates the images into explanations of behavior. Of course, there is always the possibility that after decades of exploration in

search of mind, we'll still find ourselves, metaphorically speaking, knee-deep in a swamp of neurotransmitters that may bring us no closer to a biological understanding of "mind."

It's odd to put it this way, but I may know more about how my brain works than almost any human who has ever lived, and yet that knowledge has won nothing more than a beachhead on a vast, uncharted continent. That is no small achievement, though my journey makes clear that these are early days in the brain-mapping business. I cannot say what in my genetics or upbringing might have contributed to the hive of activity we observed in the right side of my brain. Or why I remember everything about the moment when my friend D. agreed to go to the prom with me 30 years ago but nothing about the moment when she changed her mind. Given the insecurities of adolescence and the uncertainties of affection, it seemed at the time like one of those watershed moments of my life, and even now it can still produce a wince, but it appears to have eluded the gaze of the M.R.I. machine. For when we went back and examined the scans taken in the moment when I thought I'd been shown D.'s face, the data had been subsumed in a stream of average responses. It didn't leave a trace.