

CHAPTER 11

THE NEUROSCIENTISTS

IN THE NINETEENTH CENTURY, Helmholtz and Donders had begun trying to measure the capacities of the human brain. The next wave of pioneering brain scientists, a remarkable group of men and women, took their inspiration from World War II and the struggle of human operators to keep up with the staggeringly powerful machines and weapons of war.

One of these pioneers was Anne Taylor, who was a little more than five years old when World War II started and the bombs rained down. She'd hear the piercing siren. Her mother or father would scoop her up along with her younger sister, Janet, and take them down to the damp and musty cellar. They'd also take Tinkle, the family's tabby cat. And they'd wait. Sometimes they'd take their pencils and scrap paper and draw to pass the time.

As she got a bit older, still enduring the Luftwaffe's bombs, her drawings showed curious little doodles. They represented the German's deadly planes flying overhead.

When the "all clear" message would come over the loudspeakers, the family would ascend to the ground floor of their little house in Kent, England, midway between London and the Nazi airstrips in France. Her

mother was a homemaker. Her dad was a chief education officer for the Medway towns of Rochester, Gillingham, and Chatham. In the living room, there was a map on the wall with pins in it, and Anne's dad, Percy, would move the little flag pins to show what was happening at the front.

Around Britain and across the world, war raged. It was a mechanized affair. Men in planes and tanks, or armed with guns, artillery, and advanced weapons, tore apart the bodies of millions of soldiers and civilians. At the same time, not unrelated, machines were being put to important scientific use: Researchers were trying to measure the ability of pilots and soldiers to sustain their focus while operating the advanced weaponry.

How could pilots navigate these powerful planes—traveling at hundreds of miles an hour—while looking at the cockpit gauges, listening to the radio, evading anti-aircraft fire, and dogfighting? How could soldiers on the ground, bombs falling all around, call in the right coordinates for air strikes? How could the air traffic controllers keep track of the blips on the radar screen amid heavy fighting?

"People were looking at these screens, these very primitive displays, and looking for signals, like German planes coming overhead, and they often missed them," explains Alan Mackworth, a professor of computer science at the University of British Columbia, who also holds the title of Canada Research Chair in Computational Intelligence.

Mackworth wasn't born until 1945. But he well knows the science, from his own study, and because his father was smack in the middle of it. Norman Humphrey Mackworth, known as "Mack," was working for the RAF, the British air force. They weren't doing theoretical work; they were trying to save lives by helping pilots and radar operators stay alert and capable in the face of an onslaught of information.

"There was a huge crisis," says Alan. If you misread the radar screen, got distracted, fell asleep, well, people died. Villages burned. Without being too hyperbolic: Battles were won and lost, and wars, too.

There was a young man, Donald Broadbent, who volunteered for the RAF at age seventeen. He would later go on to do some of the world's pioneering work in attention science, alongside the senior Mackworth.

Broadbent's interest also stemmed from the war, and the basic day-to-day challenges he observed pilots facing as they tried to stay focused. The *New World Encyclopedia* quotes a former colleague of Broadbent's recounting an anecdote:

"The AT6 planes had two identical levers under the seat, one to pull up the flaps and one to pull up the wheels. Donald told of the monotonous regularity with which his colleagues would pull the wrong lever while taking off and crash land an expensive aeroplane in the middle of a field."

Paul Atchley, a professor of psychology at the University of Kansas, points to this collision course of man and machine during World War II as a central reason why scientists developed a new urgency around understanding the human brain.

"We had these highly motivated individuals—radar operators and pilots—who would miss attacks or drop bombs on the wrong cities. Why did they fail?"

They were running up against the limits of their own brains. "Technology was outstripping cognitive capacity," Dr. Atchley explains. "We could quantify the machine, but not the human. That's where cognitive neuroscience really started."

FOR HIS PART, NORMAN Mackworth had been born in India, the son of a British eye surgeon who performed cataract surgery for locals. The family then moved back to Britain, where Mack grew up in Aberdeen, and became a scientist, a tinkerer, a great piano player, with a bit of a short attention span himself. He was prone to moving from concept to concept, but making big strides in a handful of key scientific camps. So maybe, given his own impulse to jump around, it's not surprising that, during the war, he came up with the Mackworth Clock.

It was a black box with a point on it that turned in a circle. The point moved at regular intervals of a second. Except that sometimes it would skip the one-second interval and move after a two-second interval. Such jumps happened at periodic, unpredictable times. It was the job of an

experiment subject to press a button whenever there was a two-second jump. Simple, right?

After about thirty seconds, the subject's ability to focus—his "signal detection"—went down markedly. No wonder the radar operators, sitting eight hours a day in front of screens, could miss these life-threatening blips, these German bombers that could kill their friends and family. But why?

Unknown to little Anne Taylor, doodling to distract herself while her family tried to survive the bombs, defended by the RAF, this intersection of man and machine—the struggle to survive in wartime—was setting the stage for the next wave of attention study. What had begun with Helmholtz and Donders was taking a next major turn. And Anne, who later married and took the surname Treisman, was destined to be one of the researchers at the center of that stage.

"ANNE TREISMAN IS BRILLIANT," says Dr. Gazzaley. "She was a pioneer."

Dr. Gazzaley sits at Maverick's, an upscale eatery serving American comfort food. The restaurant is a one-minute walk from the Gazzloft, so close that Maverick's lets Dr. Gazzaley and his girlfriend, Jo, take home the plates when they order out. They're regulars here, it goes without saying, and Dr. Gazzaley, as much as he craves new experience and new stimulation, cannot help but always order the same thing: the southern-fried chicken with a biscuit and greens.

Dr. Gazzaley is nothing if not a convincing figure. He's sold five of the other six diners on the fried chicken. Patrick Martin, the big-time magician, is among them. He's got a thick build, short curly hair, wears a leather jacket, and seems to be a careful observer with a mischievous twinkle in his eye.

He promises, later in the night, maybe back at the Gazzloft when First Friday starts, to show a trick or two—to demonstrate more about the power of attention and distraction.

For now, Dr. Gazzaley is talking a bit about how attention science unfolded, and the leading researchers upon which modern work is built.

What was so amazing about Dr. Treisman?

"She was crucial in helping us understand bottom-up attention," says Dr. Gazzaley.

ANNE'S FAMILY SURVIVED THE war intact. She performed well academically; so well, in fact, that she was among just a few students from her grammar school fortunate enough to get admitted into Cambridge and Oxford. Early in life, she'd expressed an interest in the sciences, but her father thought she'd have no culture and so at Cambridge, she studied French literature.

Her success earned her an offer for a graduate fellowship, but she thought spending three years studying a single medieval poet sounded restricting. She asked Cambridge whether she might pursue a degree in psychology, which was growing in prominence and credibility.

"They said in horror: 'It's all about rats!' And I said that might be interesting."

Much of the focus in psychology at the time was around behaviorism. B. F. Skinner, John Watson, and others were focusing on the idea that human behavior could be understood by how people reacted to things; they put less focus on what was happening *inside* the brain, which seemed at the time like an inscrutable black box, the contents of which could not be observed.

Dr. Treisman was inspired to think differently by one of her instructors, Richard Gregory. He did all kinds of odd and even amusing experiments, like trying to show how vision could be impacted through neck strain, something he demonstrated by walking around the classroom wearing a heavy helmet to stress his neck muscles. Then he'd see how his vision changed. Could the physical environment change what was happening inside the head? The work was a distant echo of the work of Donders and Helmholtz, and the idea that brain activity could be measured.

By now, Norman Mackworth was the first director of the applied psychology unit at Cambridge. Working with him was Broadbent, who at seventeen had observed pilot error in the RAF, and who was on his way to becoming a godfather of cognitive psychology. After the war, he studied auditory channels, trying to understand what we focus on, and how much information we can absorb and process and under what circumstances. It was the precursor to the cocktail party effect, named by another British researcher, Edward Colin Cherry, in 1953.

Another researcher, a Canadian named Donald Hebb, was exploring a different angle. He theorized that the organization of the central nervous system and neural networks were involved with and impacted attention. His name and work would become increasingly appreciated as neuroscientists delved beyond behavioral studies and looked at the physical structures of the brain. Hebb's seminal 1949 book, *The Organization of Behavior*, illuminated a new pathway for studying the anatomy of the brain's attention networks.

These were among the seminal researchers in the field, but there were others and, collectively, with the war behind them, they had a new luxury: Gone was the immediate, life-and-death pressure of figuring out how to help pilots and radar operators sustain attention under duress. And there wasn't really a thought that technology—in a general sense—could distract people on an everyday basis.

AFTER ALL, THE DAILY dose of computers or telecommunications was still far away from most people. In 1945, for instance, AT&T began introducing a kind-of mobile phone service, derived from military radio technology, in a few metropolitan markets in the United States. Far from being ubiquitous, it could only be used simultaneously by no more than twenty people in a single city.

In 1950, about 9 percent of American homes had televisions, the first screen that would become part of most people's lives (by 1962, 90 percent of households would have one).

Researchers, absent the urgent need to know why radar operators fell asleep, started a new generation of more formal, deliberate experiments, trying to measure the capabilities of the human mind.

“Behavioral psychology was turning into the cognitive revolution,” says Dr. Treisman. How does the brain process information? How much. And, she says: “What kind of things overload the brain?”

IN 1957, TREISMAN MOVED to Oxford to pursue a PhD. She posted a flyer around campus, asking students if they’d like to be subjects in a psychology experiment, and got plenty of takers. A subject would show up in a small room with a short wooden desk adorned simply with a Brenell Mark 5 two-channel tape recorder and a pair of headphones. The subject would don the headphones and discover that each channel was playing a different passage from a book (the same book—typically, *Lord Jim* by Joseph Conrad). Dr. Treisman instructed the subject to listen to the passage coming into one ear—say, the left ear—and then to immediately repeat what he or she heard. The trick was to ignore what was coming in on the right ear.

Then Dr. Treisman added a twist. After the first fifty words or so of the recording, she switched the passages, such that what had been coming through the left ear was now coming through the right, and vice versa. About 6 percent of the time, as the subjects were repeating what they heard in the left ear, a word from the right ear, the unattended one, would slip through into their report.

To Dr. Treisman, there were two basic conclusions: first, “the attention filter is very effective,” but second, “our filter is not a total block.”

That was a relatively powerful discovery for the time. Broadbent, for one, had assumed the filter was total. He assumed people could focus on what they wanted and block out the rest. For all his contributions, Broadbent’s assumption turned out to be simplistic in much the same way that, before Helmholtz, people thought reaction time was immediate, infinite.

So what kinds of things get through the filter? What interruptions

and stimuli rise to the surface even when we’re intent on focusing on something else?

In a nearby office, a colleague of Dr. Treisman named Neville Moray made an interesting discovery also by experimenting with subjects hearing two different messages through headphones (known as the “shadowing technique”). He found that subjects listening to one message would, in only about 30 percent of cases, recognize that their own name had been said in the unattended ear, or be thrown off, derailed, by the sound of their name.

Dr. Treisman herself made an indirect discovery about the kinds of things that pop to the surface, even when we’re trying to ignore them. It happened by accident. At one point, she tried her experiment by playing passages not from *Lord Jim* but from *Doctor Zhivago* by Boris Pasternak, the book that launched the epic film. One day, a subject started doing something Dr. Treisman had never seen before: He started remarking about the passages from *Doctor Zhivago* that were being read in both ears. It appeared, on its face, to be a highly unusual capacity to attend to both streams of information.

“It turns out that he was Pasternak’s nephew,” Dr. Treisman recalls, laughing. The subject professed great familiarity with his uncle’s work. She surmised that even when we are trying to actively ignore something, we might be paying attention to it somewhere in the recesses.

“More monitoring may be going on than we realize,” Dr. Treisman says. “Even this reduced, unintended message will trigger recognition if the subject is important, relevant, or highly probable.”

DR. TREISMAN’S WORK VERIFIED the limits of the attention filter. It also provided a key building block in one of the most crucial, emerging principles of the science of attention: There is a tension going on inside the brain. It is a tug-of-war between two different aspects of the attention system, one called “bottom-up attention” and the other called “top-down attention.”

Top-down attention is what we use to direct our focus, say, on a

work project, or listening to *Lord Jim* through headphones, or when driving on the road. Top-down attention allows us to set our objectives and focus on them.

Bottom-up attention is different. It is what allows our attention to be captured instantly, without our control, say, by the sound of our name, or a bird flying by, or the ring of the phone. Bottom-up attention operates unconsciously, automatically, driven by sensory stimulus and contextual cues.

Top-down and bottom-up attentions are both essential to survival, and so is the balance between them. If we had no top-down attention, we couldn't direct our focus on important goals. But without bottom-up, we wouldn't be alerted to new stimuli, including danger. Imagine a caveman being so focused on building a fire that he never heard the lion coming through the bushes.

Before Dr. Treisman and her peers, there was a sense that people could control the direction of their attention, even if their reaction times weren't instantaneous. What Dr. Treisman and her peers began to realize and define was a powerful clash going on inside the brain.

BACK AT THE GAZZLOFT, another First Friday is about to begin. And so is Patrick, the magician. He asks if he may borrow some money from the audience. A woman produces a \$20 bill which Patrick examines with approval and just a hint of the magician's sense of drama. He stretches the bill, snaps it a couple of times, showing that it is, in fact, just a standard Andrew Jackson, nothing fancy, no tricks.

He stands beneath the tree that bisects the middle of the loft. Outside, neon light from the neighborhood leaks in from the big window. Some new music plays on Dr. Gazzaley's many speakers. But for the five partygoers who are earliest to arrive, all eyes are on Patrick. Specifically, on his hands.

With his right thumb and finger pinching the \$20 bill, he reaches his left hand into his left pocket and pulls out a lighter. He holds the flame up

to the bill. It seems to straighten a bit, get "crispy," as he puts it, though it doesn't catch fire. He's making a gentle show of his openness. Just a lighter and a bill. Just an ordinary guy. He puts the lighter back in his pocket; he must assume all eyes are trying to watch for any sleight of hand.

He shows the warmed-up bill to the woman who gave it to him. She attests to its ordinariness.

Then he balances the bill on his fingers. Then his palm. Then on three fingers. And then he turns his hand upside down so that the bill sticks to his fingers even as they're pointed downward, seeming to defy the pull of gravity for it to drop to the ground.

"This is not magic," Patrick says. "It's science."

It's impossible not to think that he had some substance on his hands, some chemical that is causing the bill to stick.

And then he takes both hands away from the \$20 bill.

And it appears to float in the air.

There is a gasp or two from the small group.

After a few seconds, Patrick blows on the bill and it floats to the ground, landing at the feet of the woman who initially handed it to him. He watches the audience look on in amazement. The woman leans down and picks up the money and shows everyone that, yes, it's just a plain old American twenty, unaltered, not sticky. There's nothing that would seem to make this bill float in the air.

Dr. Gazzaley professes to be a little conflicted by what he's seen. Like others there, he wonders whether something magic has happened and marvels at Patrick's artistry. He's also seeing the trick through another lens, a scientific one. It shows the fragility of our attention systems. Somehow, Patrick has mastered it without our awareness that he's done so. He's overtaken our top-down attention. He's got his audience thinking less and less about whether he's pulling a fast one and more about the marvelous thing they're about to see. He's transformed his goals into our goals. How will this drama end?

But, at the same time, he's perhaps toying with our bottom-up system. Somehow. By simple movements—a look here, a redirection

there—he plays to the reptilian parts of our brain that can't resist novelty, maybe important stimulation. Does a movement cause us to look away from a sleight of hand at just the right second? Does he prompt a laugh that makes it hard to focus on ferreting out the mystery?

This demonstration set the stage for the next wave of attention science, and the new discoveries as the twentieth century wore on.

“We're both interested in the same thing, but we're going at it in different ways,” Dr. Gazzaley tells Patrick. “We both want to understand how attention works. I'm trying to do it by looking inside the brain.”

The magic trick also hints at why technology plays so powerfully to our brains, and our attention systems.

In the latter half of the century, as technology moved from the military and corporate settings into our businesses and homes, the devices grew masterful at capturing our attention. It's not that they necessarily stole it from us or pulled a fast one. But the reasons we're so swept up, researchers began to understand, is because personal communications devices are unprecedented at capturing both our top-down and bottom-up attention systems, even without our awareness.

They bring us stories like Patrick the magician, engaging the top-down systems that want to find answers, complete tasks, follow narratives. They are the narrative of our lives, our work, our relationships. How will things turn out? How are we doing at work? How are things going with our spouse, or partner, or children?

And the devices do it with lights and sounds that capture us beyond our ability to control. They buzz with incoming information, chime, change colors and images that call to us. This can reinforce our goals—alerting us to important information—but also capture our attention even when we don't want it to, even when it's dangerous, like when we're behind the wheel.

Plus, Dr. Gazzaley notes, the technology companies who build the magical gadgets have every incentive to make them our irresistible companions.

“Technology companies are trying to get more of our brains per

unit time. It's as close to a business model as you can imagine. The more engaged you are in what they create, the more successful they are.

“They're driven to figure out how to engage us as immersively as possible, as deeply.”

At the beginning of the twenty-first century, scientists like Dr. Gazzaley, following the footsteps laid down by 150 years of pioneers, are using technology to home in on how our attention systems work, and they are doing so, like their predecessors, in no small part because they realize technology is putting heavy pressure on those systems, challenging the ability of its human creators to keep up.

And there is another critical piece, and another key scientist. His name is Dr. David Strayer. He's a friend and collaborator of Dr. Gazzaley. He's from Utah. And he has become the most prominent researcher to apply 150 years of attention science to a new question: How does all this technology impact the ability of drivers to focus when they're behind the wheel?