Card Sorting On Mt. Everest

Cognitive Assessment and the Application of Neuroscience

By Adrian M. Owen

In 1960, an ingenious experiment was designed to test the effects of high altitude and fatigue on cognition. The participants were all part of the Silver Hut Expedition, a Himalayan excursion led by the legendary Everest climber Sir Edmund Hillary. While sitting in their flimsy tents at 5800 meters above sea level, a group of climbers were challenged to sort cards into categories, according to their shapes, colors, and so on. The results showed that accurate work was possible at high altitude, but it just took longer.

In the 55 years or so that have passed since the Silver Hut Expedition, many of the ways that we think about assessing cognitive function remain unchanged. We cling faithfully to tests that were designed in the 1950s and 1960s to assess aspects of performance, long before we knew very much at all about the relationship between the brain and behavior. Many of these tests are based on outdated concepts like IQ and, while assessing how well a person can perform a simple task (like sorting cards), they take into account absolutely nothing of the revolution in neuroscientific understanding that has occurred over the last 25 years. But then, they were never designed with the brain in mind.

The Himalayan experiment was motivated by the eminent physiologist and biochemist Sir Joseph Barcroft, who had noted a certain amount of “bumbling at high altitude” during an expedition to Cerro de Pasco in Peru from 1920 to 1921. In 1960, card sorting was how psychologists operationalized and measured “bumbling,” but that’s all it was—a more formal measurement of performance.

In the late 1980s, I was part of a team of students, post-doctoral scientists, and faculty at the University of Cambridge who developed and tested the first computerized battery of cognitive assessment tools that were designed specifically to test human brain function. The tests were based in large part on an emerging scientific literature from neuropsychological studies of patients with damage to different parts of their brains. Those studies were beginning to reveal that the functioning (and dysfunctioning) of different brain regions, such as the frontal cortex and the temporal lobes, could be assessed directly with carefully controlled tests of memory, attention, problem solving, reasoning, and planning—all “higher cognitive functions” relatively impervious to level of education, yet also the hallmarks of many of the world’s most successful people. These computerized tools, while faster and more accurate than traditional paper and pencil tests of performance, were also a whole lot more powerful in terms of the conclusions that could be drawn about an individual and, more importantly, about his or her brain. Put simply, because they measured how well particular regions of the brain were functioning, rather than just how good a person was at any one test, the results were predictive of performance across a variety of situations requiring those parts of the brain. It was the application of neuroscience.

In the mid-1990s, I spent three years at the Montreal Neurological Institute in Canada, arguably the birthplace of human neuropsychology and its modern day incarnation, cognitive neuroscience. Functional neuroimaging techniques like positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) were just beginning to take off, allowing us, for the first time, to probe the inner workings of the healthy human brain while it went about its business.

I scanned the brains of hundreds of volunteers while they took our computerized tests of memory, attention, and planning, digging even deeper into what makes us do what we do, and why. For example, we showed that performance of any task requiring working memory is the result of a fine interplay between two regions of the frontal lobe, known as the mid-dorsolateral cortex and the mid-ventrolateral frontal cortex, respectively. Working memory is a special kind of memory that we only need to hold on to for a limited period of time, until that information is no longer needed—for example, where we parked our car this morning. How do you remember today’s parking spot and not get confused with the place that you parked yesterday, or the day before, or last week? The answer is, you have to make a special kind of memory decision; you have to decide that, of all the parking spaces that you have in your memory from days gone by, *this* is the space that you are going to remember today. This is the essence of what we call working memory.

Our computerized tests revealed that, while the mid-ventrolateral frontal cortex is responsible for laying down working memories, the mid-dorsolateral frontal cortex, is crucial for giving it the special label that makes it just relevant for today. More importantly, it’s not just about remembering your car parking space. These brain regions are crucial whether it’s a parking space, a telephone number that you need to remember just long enough to dial it into your phone, or the face of the stranger who just lent you their pen in a crowded lobby.

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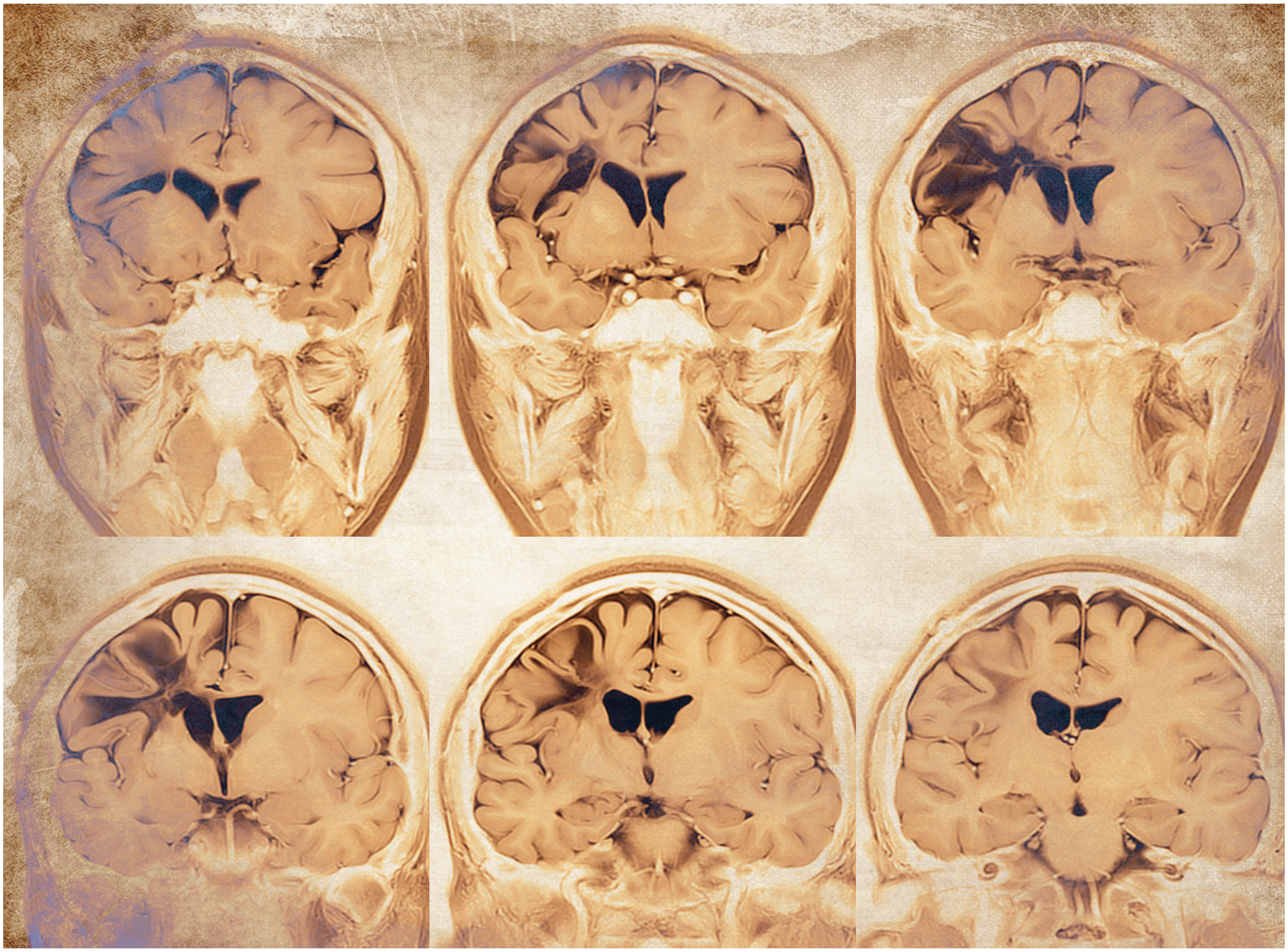
Working memory is absolutely vital for almost everything we do. And the fact that we can now measure how different parts of the brain contribute to working memory and other cognitive functions like attention, problem solving, reasoning, and decision making makes it possible for us to make predictions about how we will perform in different situations that require those functions. After all, we *are* our brains. That three-pound lump of gray and white matter inside our skulls gives rise to every thought we’ve ever had, every movement we’ve ever made, and every sensation we’ve ever experienced. In short, our brains are who we are; our brains are what make us *us*.

The single biggest change in how we investigate human brain function over the last 25 years has undoubtedly come with the advent of functional neuroimaging. But the true potential of these emerging technologies is only being fully realized now through the advent of the Internet. In the late 2000s, back in Cambridge, my team and I reconfigured our tests of cognitive assessment for Internet delivery and made them available at Cambridge Brain Sciences.

Although faster, slicker, and more sensitive than the originals, they retained all of the essential neuroscientific ingredients that 25 years of data collection had yielded. In 2010, we were approached by the BBC who asked whether our tools could be used to test the claims being made about “brain training.” Over six weeks, 11,700 members of the public kept



up a regular regime of brain training using versions of some of the most popular commercial games on the market, and we tested their brains, both before and after. The results, published in the journal *Nature*, were unequivocal. While brain training improved performance on every test that was trained, there was no overall improvement in cognitive function. In short, practice improves performance, as it does in every aspect of life, but it doesn't make you smarter.

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In 2012, we took on the concept of IQ. This time, 44,600 participants took our tests to see whether it really is true that some people are smarter than others and that this individual difference can be sensibly reduced to a single number: your IQ. The results, published in the scientific journal *Neuron*, showed quite clearly that human intelligence is not supported by a single neural system. Not that any of this was surprising; after 25 years of functional neuroimaging, if there were an "IQ spot" in the brain, then someone would have found it by now.

The Cambridge tests have gone on to be used in more than 300 studies of human brain function via the trials site at CBSTrials.com and are finding applications in pharmaceutical testing, clinical assessment, education, and HR. What are the downsides? Some fear that testing brain function is a step too far, an invasion of one's personal privacy that might reveal information best left undisclosed. But brain function is just another measurement, like height, heart rate, or performance on those traditional psychometric tests that many have relied on for so long.

If Hillary's climbers were sitting in their tents today, they would not be sorting cards. They would be logged on to the Internet while their brains were monitored in real time and compared to the brains of millions of others at sea level for signs that altitude and fatigue were affecting their cognitive function. We've come a long way in 55 years.

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