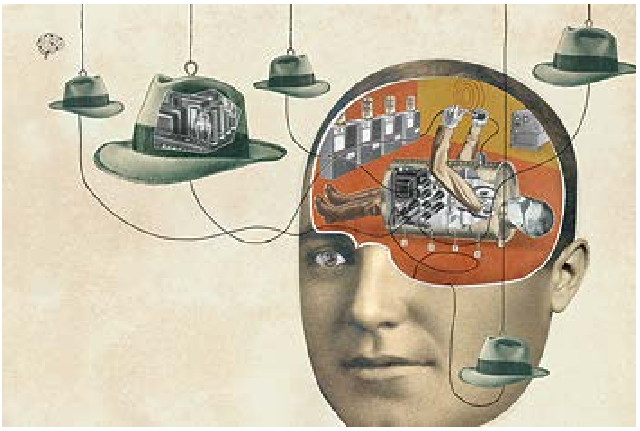
TIME Magazine
Friday, Jan 19, 2007

The Brain: How The Brain Rewires Itself

by Sharon Begley



It was a fairly modest experiment, as these things go, with volunteers trooping into the lab at Harvard Medical School to learn and practice a little five-finger piano exercise. Neuroscientist Alvaro Pascual-Leone instructed the members of one group to play as fluidly as they could, trying to keep to the metronome's 60 beats per minute. Every day for five days, the volunteers practiced for two hours. Then they took a test.

At the end of each day's practice session, they sat beneath a coil of wire that sent a brief magnetic pulse into the motor cortex of their brain, located in a strip running from the crown of the head toward each ear. The so-called transcranial-magnetic-stimulation (TMS) test allows scientists to infer the function of neurons just beneath the coil. In the piano players, the TMS mapped how much of the motor cortex controlled the finger movements needed for the piano exercise. What the scientists found was that after a week of practice, the stretch of motor cortex devoted to these finger movements took over surrounding areas like dandelions on a suburban lawn.

The finding was in line with a growing number of discoveries at the time showing that greater use of a particular muscle causes the brain to devote more cortical real estate to it. But Pascual-Leone did not stop there. He extended the experiment by having another group of volunteers merely think about practicing the piano exercise. They played the simple piece of music in their head, holding their hands still while imagining how they would move their fingers. Then they too sat beneath the TMS coil.

When the scientists compared the TMS data on the two groups--those who actually tickled the ivories and those who only imagined doing so--they glimpsed a revolutionary idea about the brain: the ability of mere thought to alter the physical structure and function of our gray matter. For what the TMS revealed was that the region of motor cortex that controls the piano-playing fingers also expanded in the brains of volunteers who imagined playing the music--just as it had in those who actually played it.

"Mental practice resulted in a similar reorganization" of the brain, Pascual-Leone later wrote. If his results hold for other forms of movement (and there is no reason to think they don't), then mentally practicing a golf swing or a forward pass or a swimming turn could lead to mastery with less physical practice. Even more profound, the discovery showed that mental training had the power to change the physical structure of the brain.

OVERTHROWING THE DOGMA

For decades, the prevailing dogma in neuroscience was that the adult human brain is essentially immutable, hardwired, fixed in form and function, so that by the time we reach adulthood we are pretty much stuck with what we have. Yes, it can create (and lose) synapses, the connections between neurons that encode memories and learning. And it can suffer injury and degeneration. But this view held that if genes and development dictate that one cluster of neurons will process signals from the eye and another cluster will move the fingers of the right hand, then they'll do that and nothing else until the day you die. There was good reason for lavishly illustrated brain books to show the function, size and location of the brain's structures in permanent ink.

The doctrine of the unchanging human brain has had profound ramifications. For one thing, it lowered expectations about the value of rehabilitation for adults who had suffered brain damage from a stroke or about the possibility of fixing the pathological wiring that underlies psychiatric diseases. And it implied that other brain-based fixities, such as the happiness set point that, according to a growing body of research, a person returns to after the deepest tragedy or the greatest joy, are nearly unalterable.

But research in the past few years has overthrown the dogma. In its place has come the realization that the adult brain retains impressive powers of "neuroplasticity"--the ability to change its structure and function in response to experience. These aren't minor tweaks either. Something as basic as the function of the visual or auditory cortex can change as a result of a person's experience of becoming deaf or blind at a young age. Even when the brain suffers a trauma late in life, it can rezone itself like a city in a frenzy of urban renewal. If a stroke knocks out, say, the neighborhood of motor cortex that moves the right arm, a new technique called constraint-induced movement therapy can coax next-door regions to take over the function of the damaged area. The brain can be rewired.

The first discoveries of neuroplasticity came from studies of how changes in the messages the brain receives through the senses can alter its structure and function. When no transmissions arrive from the eyes in someone who has been blind from a young age, for instance, the visual cortex can learn to hear or feel or even support verbal memory. When signals from the skin or muscles bombard the motor cortex or the somatosensory cortex (which processes touch), the brain expands the area that is wired to move, say, the fingers. In this sense, the very structure of our brain--the relative size of different regions, the strength of connections between them, even their functions--reflects the lives we have led. Like sand on a beach, the brain bears the footprints of the decisions we have made, the skills we have learned, the actions we have taken.

SCRATCHING A PHANTOM LIMB

An extreme example of how changes in the input reaching the brain can alter its structure is the silence that falls over the somatosensory cortex after its owner has lost a limb. Soon after a car crash took Victor Quintero's left arm from just above the elbow, he told neuroscientist V.S. Ramachandran of the University of California at San Diego that he could still feel the missing arm. Ramachandran decided to investigate. He had Victor sit still with his eyes closed and lightly brushed the teenager's left cheek with a cotton swab.

Where do you feel that? Ramachandran asked. On his left cheek, Victor answered--and the back of his missing hand. Ramachandran stroked another spot on the cheek. Where do you feel that? On his absent thumb, Victor replied. Ramachandran touched the skin between Victor's nose and mouth. His missing index finger was being brushed, Victor said. A spot just below Victor's left nostril caused the boy to feel a tingling on his left pinkie. And when Victor felt an itch in his phantom hand, scratching his lower face relieved the itch. In people who have lost a limb, Ramachandran concluded, the brain reorganizes: the strip of cortex that processes input from the face takes over the area that originally received input from a now missing hand. That's why touching Victor's face caused brain to "feel" his missing hand.

Similarly, because the regions of cortex that handle sensations from the feet abut those that process sensations from the surface of the genitals, some people who have lost a leg report feeling phantom sensations during sex. Ramachandran's was the first report of a living being knowingly experiencing the results of his brain rewiring.

THINKING ABOUT THINKING

As scientists probe the limits of neuroplasticity, they are finding that mind sculpting can occur even without input from the outside world. The brain can change as a result of the thoughts we think, as with Pascual-Leone's virtual piano players. This has important implications for health: something as seemingly insubstantial as a thought can affect the very stuff of the brain, altering neuronal connections in a way that can treat mental illness or, perhaps, lead to a greater capacity for empathy and compassion. It may even dial up the supposedly immovable happiness set point.

In a series of experiments, for instance, Jeffrey Schwartz and colleagues at the University of California, Los Angeles, found that cognitive behavior therapy (CBT) can quiet activity in the circuit that underlies obsessive-compulsive disorder (OCD), just as drugs do. Schwartz had become intrigued with the therapeutic potential of mindfulness meditation, the Buddhist practice of observing one's inner experiences as if they were happening to someone else.

When OCD patients were plagued by an obsessive thought, Schwartz instructed them to think, "My brain is generating another obsessive thought. Don't I know it is just some garbage thrown up by a faulty circuit?" After 10 weeks of mindfulness-based therapy, 12 out of 18 patients improved significantly. Before-and-after brain scans showed that activity in the orbital frontal cortex, the core of the OCD circuit, had fallen dramatically and in exactly the way that drugs effective against OCD affect the brain. Schwartz called it "self-directed neuroplasticity," concluding that "the mind can change the brain."

The same is true when cognitive techniques are used to treat depression. Scientists at the University of Toronto had 14 depressed adults undergo CBT, which teaches patients to view their own thoughts differently--to see a failed date, for instance, not as proof that "I will never be loved" but as a minor thing that didn't work out. Thirteen other patients received paroxetine (the generic form of the antidepressant Paxil). All experienced comparable improvement after treatment. Then the scientists scanned the patients' brains. "Our hypothesis was, if you do well with treatment, your brain will have changed in the same way no matter which treatment you received," said Toronto's Zindel Segal.

But no. Depressed brains responded differently to the two kinds of treatment--and in a very interesting way. CBT muted overactivity in the frontal cortex, the seat of reasoning, logic and higher thought as well as of endless rumination about that disastrous date. Paroxetine, by contrast, raised activity there. On the other hand, CBT raised activity in the hippocampus of the limbic system, the brain's emotion center. Paroxetine lowered activity there. As Toronto's Helen Mayberg explains, "Cognitive therapy targets the cortex, the thinking brain, reshaping how you process information and changing your thinking pattern. It decreases rumination, and trains the brain to adopt different thinking circuits." As with Schwartz's OCD patients, thinking had changed a pattern of activity--in this case, a pattern associated with depression--in the brain.

HAPPINESS AND MEDITATION

Could thinking about thoughts in a new way affect not only such pathological brain states as OCD and depression but also normal activity? To find out, neuroscientist Richard Davidson of the University of Wisconsin at Madison turned to Buddhist monks, the Olympic athletes of mental training. Some monks have spent more than 10,000 hours of their lives in meditation. Earlier in Davidson's career, he had found that activity greater in the left prefrontal cortex than in the right correlates with a higher baseline level of contentment. The relative left/right activity came to be seen as a marker for the happiness set point, since people tend to return to this level no matter whether they win the lottery or lose their spouse. If mental training can alter activity characteristic of OCD and depression, might meditation or other forms of mental training, Davidson wondered, produce changes that underlie enduring happiness and other positive emotions? "That's the hypothesis," he says, "that we can think of emotions, moods and states such as compassion as trainable mental skills."

With the help and encouragement of the Dalai Lama, Davidson recruited Buddhist monks to go to Madison and meditate inside his functional magnetic resonance imaging (fMRI) tube while he measured their brain activity during various mental states. For comparison, he used undergraduates who had had no experience with meditation but got a crash course in the basic techniques. During the generation of pure compassion, a standard Buddhist meditation technique, brain regions that keep track of what is self and what is other became quieter, the fMRI showed, as if the subjects--experienced meditators as well as novices--opened their minds and hearts to others.

More interesting were the differences between the so-called adepts and the novices. In the former, there was significantly greater activation in a brain network linked to empathy and maternal love. Connections from the frontal regions, so active during compassion meditation, to the brain's emotional regions seemed to become stronger with more years of meditation practice, as if the brain had forged more robust connections between thinking and feeling.

But perhaps the most striking difference was in an area in the left prefrontal cortex--the site of activity that marks happiness. While the monks were generating feelings of compassion, activity in the left prefrontal swamped activity in the right prefrontal (associated with negative moods) to a degree never before seen from purely mental activity. By contrast, the undergraduate controls showed no such differences between the left and right prefrontal cortex. This suggests, says Davidson, that the positive state is a skill that can be trained.

For the monks as well as the patients with depression or OCD, the conscious act of thinking about their thoughts in a particular way rearranged the brain. The discovery of neuroplasticity, in particular the power of the mind to change the brain, is still too new for scientists, let alone the rest of us, to grasp its full meaning. But even as it offers new therapies for illnesses of the mind, it promises something more fundamental: a new understanding of what it means to be human.

.

source: http://www.time.com/time/magazine/article/0,9171,1580438,00.html