How we think

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ABSTRACT (ABSTRACT)

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ABSTRACT

Psychologist Steven Pinker challenges the accepted wisdom of how the human brain works. Critics wonder if Pinker and other researchers are being seduced by a technology that reveals biological responses that may have nothing to do with the questions being asked.

FULL TEXT

For hours at a time, psychologist Steven Pinker subjects some of America's brightest university students to a battery of real and imaginary words. What is the past tense of "slace" or "plip"? he asks. What is the past of to "see" with your eyes, or to "saw" with a saw? See-saw-sawed. Confronted with something as mighty as a word, the human mind takes all of a quarter of a second to store it (for most people in the rear of the left hemisphere) and then ship it out for processing to word-fetching memory banks or the rule-making generating stations in different parts of the brain. Asked to deal with made-up words, the mind shows an equal dexterity in drawing meaning and grammatical correctness, barely missing a beat. Pinker can see this happen on a computer screen: his subjects are contemplating the peculiarities of the English language while the magnetic activity in their brains is being measured to within one-hundredth of a second. The results of all these mental gymnastics send brightly coloured tracers slacing across a computerized map of the brain in a real-life game of Pong.

From his perch as a professor of cognitive neuroscience at the prestigious Massachusetts Institute of Technology, the Montreal-born Pinker has a touching faith in the brainwaves of 19-year-olds. "As a scientist, I have been trained not to trust anything unless it can be verified in the lab on the brains of rats or sophomores," he says with the dry wit that has made him a sought-after guest at high-table seminars, on The New York Times commentary pages, even on TV talk shows. But the 45-year-old Pinker is more than just a walking one-liner or even the latest academic superstar. He is at the epicentre of a growing group of mostly youngish researchers in different fields who are using the latest imaging technology to map the biology of the brain and, with the audacity that only science can muster, dare to explain how the mind works.

Canadian scientists have long been at the forefront of research into the brain, partly because of the pioneering efforts at the Montreal Neurological Institute during the 1940s and '50s. Alan Evans, a top MNI researcher, is part of an international team that recently showed the brain developing and reorganizing its real estate for much longer in life than was previously thought. In Hamilton, McMaster University psychiatrist and neuroscientist Sandra Witelson, like Pinker a graduate of Montreal's McGill University, made waves last year for revealing the tantalizing structural mysteries of Einstein's brain.

But respected as these and many other researchers are in their own fields, none has achieved Pinker's profile. Maybe it is because of the rock-star looks that can seem a tad out of place in today's academia. More likely it is because of a wide-ranging intellect that makes Pinker that rare breed -- a serious scientist with a common touch and a genius for confronting orthodoxy and standing his ground in academic food fights.

In person and on a lecture stage, Pinker is endearingly Canadian: polite, soft-spoken, attentive to what others say. His strength is that he doesn't just study language, he wields it like a sword, cutting through pomp and political correctness to explain everything from the origins of grammar to the evolutionary underpinnings of guilt, pornography, infanticide, even humour.

But there is another side to Pinker, too: quirky, non-conformist, competitive, perhaps to be expected for a big-brained primate who has spent the past 23 years in Boston's Harvard-MIT nexus, a notorious bastion of catty intellectualism. His very public feud about the evolutionary basis of the mind with Harvard paleo-biologist Stephen Jay Gould -- another elegant popularizer -- was part of a debate that went on for weeks in The New York Review of Books before ending up on the front page of The Boston Globe. There is also a hint here of the angry young man as scientist: "Every idea in the book may turn out to be wrong," Pinker wrote in the introduction to his 1997 best-seller, How the Mind Works. "But that would be progress, because our old ideas were too vapid to be wrong."

In his corner office at the fringe of MIT's sprawling, neoclassical-style campus across the Charles River from a tony residential section of Boston, Pinker has an ideal spot to absorb all that modern science has to offer on the brain, from linguists like the celebrated Noam Chomsky, a couple of buildings away, to one of the world's largest centres for the study of robots and artificial intelligence. "Language is my work," he says. "The rest" -- referring to his theories of how the mind works -- "is kind of a hobby." It is a "hobby," mind you, that nearly earned him the Pulitzer Prize two years ago and has him dangerously close to becoming a cultural icon, the New Age guru for the machinery of thought.

His three most recent books on language and the mind have been popular best-sellers. Top British and American newspapers and magazines have published admiring profiles. Not bad for a studious Montrealer, the eldest of three siblings, all professionals, who describes himself as an "erstwhile '60s radical" come late to the party. Before McGill, he went to Montreal's celebrated "hippie college," Dawson, from 1971 to 1973. "But I was hardly a hippie," he says. Pinker didn't do drugs or drink but tripped out on the excitement of exploring what made people tick. "When I discovered you could bring someone into a lab and ask questions about human behaviour," he says, "that's when everything fell into place." And he's been grooving on that ever since.

Is the human mind a clean slate on which is writ the sum total of an individual's life -- upbringing, schooling, personal relationships, the myriad cultural refinements that flow from things like television or good books? That may be the dominant view. Or is it, in effect, a giant computer, preprogrammed in large measure from humanity's earliest endeavours -- and with a good number of those early hunter-gatherer quirks still intact? Pinker thinks that's the case, though he is quick to note that this does not mean human behaviour is preprogrammed as well. Scientists may yet find a specific location in the brain for jealousy or adultery. But those behaviours will be played out "among many mental modules," Pinker says, not to mention the chessboard of other people's behaviour and expectations.

"Now, for more and more things that you and I actually talk about in conversation, we are starting to find a home in the brain," says Pinker. He would include concepts like social intelligence (the ability to impute motive and desires to other people), a sense of justice, and romantic love as being hard-wired in large measure in the brain through hundreds of thousands of years of evolution. Some scientists claim to have located a brain site for humanity's moral compass. (It's in the ridge of grey matter just behind the eyeballs. The sociopath's brain would have a shrunken version.) Want to know why teenagers won't do their term projects until the very last minute? According to some neuroscientists, it is because their frontal cortex, the place for future-based decision-making, is still being formed.

These beliefs are not universally held. Critics wonder if Pinker and other researchers are being seduced by a technology that reveals biological responses that may have nothing to do with the questions being asked. Magnetic resonance imaging (MRI), one of the new, relatively unobtrusive techniques for taking pictures of the brain's activity, is notoriously complex. Researchers find that repeating a test does not always produce the same response each time: the mind, it seems, likes novelty.

Still, the mere fact that researchers at scores of centres around the world are fixing similar cognitive functions in well-documented locations suggests very strongly that the human brain is built in a particular way. And regardless of the academic quarrelling, there is no disputing that a decade of increasingly sophisticated examination has produced a concept of the brain, especially regarding such key areas as memory, development, gender differences, language and emotion.

McGill's MNI, for example, recently won a $22-million grant to establish the world's first neuroanatomy atlas for children. It will use data from eight hospitals and research centres in North America to correlate brain development with behaviour. "Within 10 to 15 years, there is going to be a huge amount of evidence setting out the biological basis for variations in behaviour," says McMaster's Witelson. "That's where the field is going."

That's where Pinker is heading as well. How the Mind Works is an ambitious, 660-page tome that seeks to explain everything from artificial intelligence to hotheadedness. His latest offering, Words and Rules, is ostensibly about the quirky nature of regular and irregular verbs in the English language. But in Pinker's hands, the subject becomes much more -- a way of understanding the double-barrelled approach with which the mind seems to process information.

Other scientists are finding this, too, notably Michael Petrides at McGill. He argues there are (at least) two distinct levels, both in the prefrontal cortex, for processing thought. And they are not based on the thing that is being processed, whether it is a place or an object, but on the abstractness of the thought itself. For Pinker, language is made up of both memory for sounds and symbols, and instinctual, built-in rules that generate grammar and meaning. The two processes appear to stem from different places in the brain and, Pinker suggests, may be a model for how the mind deals with other important cognitive functions.

It is a view that has reignited the nature versus nurture debate. It sees the human brain as a system of organs that has evolved to include specialized functions, with their own software, to deal with some of the basic imperatives of life: language, reproduction, kinship, social responsibilities, fear and emotion, an awareness of place. Complicated ideas are built out of simple ones, just as complex sentences are built from simple rules and sounds.

Some of the brain's software -- say, sexual jealousy or a disgust at eating insects -- may be out of date, left over from life on the African plains eons ago. But it may still play a part in how we live our lives or, in some instances, in how we try to heal the brain from injury or psychiatric disorder. Pinker, who quotes extensively from the work of evolutionary psychologists, nonetheless says it is naive to think the modern mind works simply according to evolutionary dictates. Rather than nature versus nurture, he says, it is better to think of the brain as a biological machine that combines both -- constantly, maybe even in the nanosecond it takes to fire a neuron -- in a kind of see-saw, slip-"slace" battle between the new and the genetically acquired.

Mood and the mind

Helen Mayberg makes people sad. An otherwise cheery and polite neurologist at the Rotman Research Institute in Toronto, Mayberg is unapologetic about what she does: "If you take normal, healthy people and ask them to read something they've written about a traumatic event in their lives, within four minutes they become tearful." And within that period of time, the brain undergoes a remarkable transformation.

Emotion is among the least studied of cognitive functions. But modern imaging research is starting to show two distinct patterns. One is that the brain biology of people experiencing transient sadness -- such as Mayberg's test patients -- is similar to that of others with deep-seated depression. That suggests that sadness and depression have much in common and that some minds just aren't able to switch out of that state. The other pattern is that intense emotion sets up a tug of war between the ancient limbic system and the more modern cortex, especially the frontal lobes where thinking and planning take precedence. As sadness or depression progresses, the limbic system goes into overdrive, firing its neurons while the thinking part shuts down. "The brain may be forced to pick and choose," says Mayberg. "You can't sneeze and keep your eyes open at the same time. That's hard-wired. Maybe it's the same with emotion." Depressed people, she says, have tremendous difficulty concentrating even on ordinary tasks. Healthy people can snap out of sadness as the thinking part of the brain fights back.

Some suggest that emotion evolved in the first place because of a need to back up promises and threats: the intellect ceding partial control to the passions. Who will believe the threat of deadline unless an editor is willing to throw a tantrum now and then? Fear seems to set up a mental battle between the quick-response and the more analytical mechanisms in the brain. And fear may in fact be several emotions. Phobias about physical things or social scrutiny respond to different drugs, suggesting they belong to different neural networks.

How memory works

The good news is that memory is cached in many more parts of the brain than was previously thought. Researchers are also finding at least some capacity for the mind to reorganize itself and relearn important functions after stroke or injury. The bad news: you still can't tell your brain to remember something on command. "Intention itself is a relatively feeble method of committing a name or a fact to memory," laughs the University of Toronto's Endel Tulving, at 73 the grandfather of memory research in this country. The brain, it seems, has its own rationale for deciding what should be remembered and what shouldn't. Some of it may be purely chemical: Princeton University scientist Joe Tsien has made a "smarter" mouse by adding a chemical receptor to its genetic makeup to strengthen the synapses, the sites where two nerve cells touch. The result: the mouse has a better memory for fear and reward.

Ten years ago, scientists felt that almost all memory was situated in the hippocampus, a seahorse-shaped organ embedded in the centre of the brain. Now, because of brain imaging techniques, they are seeing the machinery of thought operate in a much more far-flung manner. Imaging shows the brain works harder -- has more active areas -- when processing words than when dealing with visual images, even though visual scenes are by far more easily remembered.

Tulving says there are probably at least five memory systems, each with its own properties and processes. Short-term or working memory is located in the frontal cortex behind the forehead. It is the part of the brain that enables us to follow conversations, to remember telephone numbers (on a good day) and, some say, to act as a clearinghouse for decision-making -- sending sensory information to other parts of the brain for deeper cogitation. New research is showing that working memory has its own specific brain chemistry.

Long-term memory would include procedural memory (how to ride a bike, type or speak); priming memory (recognizing objects and words); semantic memory (general knowledge of the world through books, television and common experiences like standing in the rain to know it's wet); and episodic memory (direct personal experiences). Of these, Tulving says, only episodic has to do with the past and fits the common notion of memory being dredged up or being "remembered." The others are more a biological process of action and reaction: a face triggers a name, which triggers a complex set of greetings and interaction, some of which -- if the brain decides it's relevant -- gets stored for future use.

Size and intelligence

Sandra Witelson, a demure woman who has held the preserved brain of Albert Einstein in her hands and studied it for science, takes a moment to ponder whether people with larger brains are smarter. "That may be the case," the McMaster neuroscientist says cautiously. But more important than overall size is structure, or the size of specific regions -- Einstein's brain being a case in point. The brain of the man who upended 300 years of scientific tradition is of average male size, not out of line with any of the 64 other brains in Witelson's eclectic collection. But it had two unusual characteristics. One is that the parietal lobes, the grey matter just back of the ears where problem-solving and visualization occur, are about a centimetre -- or 15 per cent -- wider than a standard brain's. The other is that Einstein's Sylvian fissure, the crevice that flows through the area in the brain servicing mathematical reasoning and visualization, has a noticeably unique route along the surface, leaving these two areas much more densely packed together. "Every brain is different just like every face is different," says Witelson. "But we have never seen anything like this before."

Einstein's rerouted fissure may be a developmental quirk that occurred at birth. Or it may be a genetic or environmental twist that will eventually show up in other individuals with highly developed spatial skills. Witelson is eager to test that hypothesis. Brain imaging is starting to pick up other features that are unique to certain individuals -- an enlargement of the auditory cortex in those with perfect pitch, for example -- and is continuing to define the structural differences between the sexes.

Broadly speaking, the brain is divided into two hemispheres, with language skills located primarily in the left, and spatial skills in the right. Many studies have shown that women's language skills are more equally distributed between the two halves -- a distinct advantage if stroke or injury affects the left hemisphere. And recent studies are showing that the differences in the brains of men and women extend right down to the cellular and chemical level, even to the way cells in parts of the cortex are packed and organized.

In March, a German team using brain-imaging techniques reported that men escaped a virtual-reality maze much faster than women -- in an average of two minutes and 22 seconds compared with three minutes and 16 seconds. More intriguing, perhaps, they discovered that the sexes often used different areas of the brain to navigate: men relied on the left hippocampus, a memory region that specializes in spatial tasks; women tended to use more of the parietal and prefrontal areas, which are linked to visual clues and reasoning. Oddly, perhaps, the hippocampus in women tends to be larger, a refinement that may explain why women suffer less memory loss with Alzheimer's disease.

Men, however, have a larger corpus callosum, the neural pathway that links the two hemispheres. "The research is suggesting that the relationship between anatomy and cognition is different in each sex," says Witelson. "It is like two different automobiles. Each has a motor, a steering mechanism and brakes. But one is a Volvo and the other is a Lexus -- and I'm not for an instant implying which sex is which."

The maturing brain

In the first three years of life, the human brain is a veritable factory of neural development. Trillions of synaptic circuits that will last a lifetime are being formed. Just to grow the brain, young children use twice as much energy in their heads as adults, who carry about all the cares of the world. But scientists are now discovering that the brain can grow and reorganize itself, within limits, past puberty and possibly well into adulthood, depending on the demands put on it. A British study released in March showed that the brains of cab drivers ranging in age from 32 to 62 had experienced a "relative redistribution of grey matter" in the memory-focusing hippocampus. The researchers attributed the change to having to learn to navigate the labyrinthine streets of London.

"Simply put, the brain is a riot of functional changes," says the MNI's Evans. What's more, the maturing brain, awash in distinct stages of chemical and hormonal development, is like nature's wild garden: the grey matter grows more synapses than it needs, then spends part of its development "pruning" or leaving aside areas that are not put to use.

Between 6 and 15 are the peak language years when the left (language) hemisphere fills out. Some scientists believe the window shuts at about 11 or 12, at the onset of puberty, when learning new languages becomes much more difficult. Studies of children with damaged left hemispheres show that their language skills can be reorganized, within limits, on the right side before puberty; after that the right hemisphere has pretty well settled into a different way of ordering its world.

The brains of teenagers are definitely a work in progress. Hormones push the limbic system, where raw emotion is seated, into overdrive. At the same time, the frontal cortex, where cool-headed decision-making takes place, is still trying to get its act together. This back and forth may explain why teenagers can't seem to choose between talking on the phone or doing their homework when a term paper looms; and why social situations and insults become so important: they are still sorting out the social signals. One study showed adults and teenagers images of faces contorted in fear. All the adults recognized the emotion; many teens didn't. Scans also showed the adults and teens used different areas of their brains during the experiment.

The language instinct

When an almost three-year-old says, "I breaked the window," she is saying what all kids do at that age. "Everyone," says Steven Pinker, "without fail." And there's the rub. Children do not hear a verb like that from their parents -- they deduce them, says Pinker, from rules that follow a logic buried in their brains from time immemorial. That logic -- a language instinct akin to learning how to walk -- allows them to hear a few thousand sentences, then produce an almost unlimited number of their own. Children soak up language "not quite like a sponge," says Pinker. There is a lot of symbol crunching involved, a lot of deduction. Some linguists argue that instinctual rules are the basis of all language. Others say there are no rules, just patterns of association that children pick up on. Pinker says both apply.

Irregular verbs such as to be, to go or to do (there are 164 in English) were once generated by rules that have been bastardized over the ages. Now, they must be remembered. Imaging research shows different parts of the brain light up for rule-based regular words as opposed to memorized irregular ones. Unfortunately for some researchers, the areas in use vary from study to study. But illness offers a better clue. Patients in the early stages of Alzheimer's have trouble remembering words, but can still speak in fluent, mostly grammatical sentences; people with Parkinson's disease, on the other hand, have the opposite tendency -- an indication of two distinct pathways in the brain.

It is possible that instinctual rules evolved -- they can be found in every language, Pinker believes -- only for language. But perhaps they also evolved to help humans think in broad categories. Someone can be "grandmotherly" without ever having borne children; "game" can mean anything from solitaire to hockey. Thought is not sifting, at incredible speeds, through a mental file cabinet of stereotypes. Nor is conversation. They occur naturally, by deduction, by prediction, by cranking through a chain of implications where one notion triggers another. And they occur by reading the subtle clues that humans give off, whether it is in the face, the tone of voice or the curious inflections at the end of sentences that can vary from culture to culture. That, says Pinker, is how the mind works.

Laughter, depression, math skills, intuition, problem-solving, geography, grammar, face memory, language skills. Scientists are locating the sites in the brain for all those functions and more with increasing levels of sophistication. They are confident they know where the impetus for voluntary movement--shaking hands, for instance--takes place. And where the ability to read braille and understand sign language is stored. A team of researchers at the Montreal Neurological Institute recently isolated a region that responds to the human voice, whether speaking, coughing or humming--distinct from the region that responds to other sounds. Faces are remembered in a particular part of the brain; other things are handled elsewhere. And when you chuckle at a punch line, it's the area just behind the right eyeball that got the joke.

(See print copy for complete diagram.)

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DETAILS

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