Don't just stand there, think

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New research suggests that we think not just with our brains, but with our bodies

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WHEN YOU READ something confusing, or work a crossword puzzle, or try to remember where you put your keys, what do you do with your body? Do you sit? Do you stand? Do you pace? Do you do anything with your hands? Do you move your eyes in a particular pattern?

How you answer questions like these, it turns out, may determine how long it will take for you to decipher what you're reading, solve your puzzle, or get your keys back.

The brain is often envisioned as something like a computer, and the body as its all-purpose tool. But a growing body of new research suggests that something more collaborative is going on - that we think not just with our brains, but with our bodies. A series of studies, the latest published in November, has shown that children can solve math problems better if they are told to use their hands while thinking. Another recent study suggested that stage actors remember their lines better when they are moving. And in one study published last year, subjects asked to move their eyes in a specific pattern while puzzling through a brainteaser were twice as likely to solve it.

The term most often used to describe this new model of mind is "embodied cognition," and its champions believe it will open up entire new avenues for understanding - and enhancing - the abilities of the human mind. Some educators see in it a new paradigm for teaching children, one that privileges movement and simulation over reading, writing, and reciting. Specialists in rehabilitative medicine could potentially use the emerging findings to help patients recover lost skills after a stroke or other brain injury. The greatest impact, however, has been in the field of neuroscience itself, where embodied cognition threatens age-old distinctions - not only between brain and body, but between perceiving and thinking, thinking and acting, even between reason and instinct - on which the traditional idea of the mind has been built.

"It's a revolutionary idea," says Shaun Gallagher, the director of the cognitive science program at the University of Central Florida. "In the embodied view, if you're going to explain cognition it's not enough just to look inside the brain. In any particular instance, what's going on inside the brain in large part may depend on what's going on in the body as a whole, and how that body is situated in its environment."

Or, as the motto of the University of Wisconsin's Laboratory of Embodied Cognition puts it, "Ago ergo cogito": "I act, therefore I think."

The emerging field builds on decades of research into human movement and gesture. Much of the earlier work looked at the role of gestures in communication, asking whether gesture grew out of speech or exploring why people gestured when they were talking on the telephone.

But today, neuroscientists, linguists, and philosophers are making much bolder claims. A few argue that human characteristics like empathy, or concepts like time and space, or even the deep structure of language and some of the most profound principles of mathematics, can ultimately be traced to the idiosyncrasies of the human body. If we didn't walk upright, for example, or weren't warm-blooded, they argue, we might understand these concepts totally differently. The experience of having a body, they argue, is intimately tied to our intelligence.

"If you want to teach a computer to play chess, or if you want to design a search engine, the old model is OK," says Rolf Pfeifer, director of the artificial intelligence lab at the University of Zurich, "but if you're interested in understanding real intelligence, you have to deal with the body."

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Embodied cognition upends several centuries of thinking about thinking. Rene Descartes, living in an age when steam engines were novelty items, envisioned the brain as a pump that moved "animating fluid" through the body - head-shrinkers through the ages have tended to enlist the high-tech of their day to describe the human cognitive system - but the mind, Descartes argued, was something else entirely, an incorporeal entity that interacted with the body through the pineal gland.

While a few thinkers, most notably the French philosopher Maurice Merleau-Ponty in the 1940s, challenged Descartes' mind-body separation, it remained the dominant model up through the 20th century, though its form evolved with the times. After the development of the modern computer in the years after World War II, a new version of the same model was adopted, with the brain as a computer and the mind as the software that ran on it.

In the 1980s, however, a group of scholars began to contest this approach. Fueled in part by broad disappointment with artificial-intelligence research, they argued that human beings don't really process information the way computers do, by manipulating abstract symbols using formal rules. In 1995, a major biological discovery brought even more enthusiasm to the field. Scientists in Italy discovered "mirror neurons" that respond when we see someone else performing an action - or even when we hear an action described - as if we ourselves were performing the action. By simultaneously playing a role in both acting and thinking, mirror neurons suggested that the two might not be so separate after all.

"You were seeing the same system, namely the motor system, playing a role in communication and cognition," says Arthur Glenberg, a professor of psychology and head of the embodied cognition laboratory at Arizona State University.

This realization has driven much of the recent work looking at how moving and thinking inform and interfere with each other. For example, a pair of studies published in 2006 by Sian Beilock, now an assistant professor of psychology at the University of Chicago, and Lauren Holt, one of her former students, examined how people who were good at certain physical activities thought about those activities.

In one study, Beilock and Holt had college hockey players, along with a non-hockey-player control group, read a sentence, sometimes hockey-related, sometimes not. Then the subjects would be shown a picture and asked if it corresponded with the sentence. Hockey players and non-hockey players alike almost invariably answered correctly, but on the hockey-related sentences the response times of the hockey players were significantly faster than the nonplayers. In a second study, the researchers found similar results with football players. According to Beilock, the difference in response time wasn't a matter of knowledge - after all, all of the subjects in the study got the vast majority of the questions right. What it suggested, Beilock argues, is that the athletes' greater store of appropriate physical experiences served as a sort of mental shortcut.

"People with different types of motor experiences think in different ways," she argues.

These sorts of results aren't simply limited to thinking about sports, or other highly physical activities. A 2003 study by Michael Spivey, a psychology professor at Cornell, and his student Elizabeth Grant, found that people who were given a tricky spatial relations brainteaser exhibited a distinctive and unconscious pattern of eye movements just before they arrived at the answer. The subjects seemed to unconsciously work through the problem by enacting possible solutions with their gaze.

A study published in August by Alejandro Lleras and Laura Thomas, two psychologists at the University of Illinois, built on those results by inducing the eye movements Spivey had discovered. Lleras and Thomas found that doing so greatly improved the rate at which people solved the problem - even though most never figured out that the eye movements had anything to do with it.

"The subjects actually think that the eye-tracking task is very distracting," Lleras says. "They think we're doing this to keep them from solving the problem."

Other studies have looked at non-spatial problems and at memory. Work led by Susan Goldin-Meadow, a psychology professor at the University of Chicago, has found that children given arithmetic problems that normally would be too difficult for them are more likely to get the right answer if they're told to gesture while thinking. And studies by Helga Noice, a psychologist at Elmhurst College, and her husband Tony Noice, an actor and director, found that actors have an easier time remembering lines their characters utter while gesturing, or simply moving.

The body, it appears, can subtly shape people's preferences. A study led by John Cacioppo, director of the Center for Cognitive and Social Neuroscience at the University of Chicago, found that subjects (all non-Chinese speakers) shown a series of Chinese ideographs while either pushing down or pulling up on a table in front of them will say they prefer the ideographs they saw when pulling upward over the ones they saw while pushing downward. Work by Beilock and Holt found that expert typists, when shown pairs of two-letter combinations and told to pick their favorite, tend to pick the pairs that are easier to type - without being able to explain why they did so.

What's particularly interesting to neuroscientists is the role that movement seems to play even in abstract thinking. Glenberg has done multiple studies looking at the effect of arm movements on language comprehension. In Glenberg's work, subjects were asked to determine whether a string of words on a computer screen made sense. To answer they had to reach toward themselves or away from themselves to press a button.

What Glenberg has found is that subjects are quicker to answer correctly if the motion in the sentence matches the motion they must make to respond. If the sentence is, for example, "Andy delivered the pizza to you," the subject is quicker to discern the meaning of the sentence if he has to reach toward himself to respond than if he has to reach away. The results are the same if the sentence doesn't describe physical movement at all, but more metaphorical interactions, such as "Liz told you the story," or "Anne delegates the responsibilities to you."

The implication, Glenberg argues, is that "we are really understanding this language, even when it's more abstract, in terms of bodily action."

Some linguists, cognitive scientists, and philosophers go further - arguing that the roots of even the most complex and esoteric aspects of human thought lie in the body. The linguist George Lakoff, of the University of California, Berkeley, along with Rafael Nunez, a cognitive scientist at the University of California, San Diego, have for several years advanced the argument that much of mathematics, from set theory to trigonometry to the concept of infinity, derives not from immutable properties of the universe but from the evolutionary history of the human brain and body. Our number system, they argue, and our understanding of addition and subtraction emerge from the fact that we are bipedal animals that measure off distances in discrete steps.

"If we had wheels, or moved along the ground on our bellies like snakes," Lakoff argues, "math might be very different."

These ideas have met intense opposition among mathematicians, but also among some cognitive scientists, who believe they reflect an overreaching reading of a promising but still sketchy set of experimental results.

"I think these findings are really fantastic and it's clear that there's a lot of connection between mind and body," says Arthur Markman, a professor of psychology at the University of Texas. He remains skeptical, though, that the roots of higher cognition will be found in something as basic as the way we walk or move our eyes or arms.

"Any time there's a fad in science there's a tendency to say, 'It's all because of this,'" Markman says. "But the thing in psychology is that it's not all anything, otherwise we'd be done figuring it out already."

While embodied cognition remains a young field, some specialists believe that it suggests a rethinking of how we approach education. Angeline Lillard, a psychology professor at the University of Virginia, says that one possibility is to take another look at the educational approach that Italian educator Maria Montessori laid out nearly 100 years ago, theories that for decades were ignored by mainstream educators. A key to the Montessori method is the idea that children learn best in a dynamic environment full of motion and the manipulation of physical objects. In Montessori schools, children learn the alphabet by tracing sandpaper letters, they learn math using blocks and cubes, they learn grammar by acting out sentences read to them.

To Lillard, the value of embodied cognition in education is self-evident.

"Our brains evolved to help us function in a dynamic environment, to move through it and find food and escape predators," she says. "It didn't evolve to help us sit in a chair in a classroom and listen to someone and regurgitate information."

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