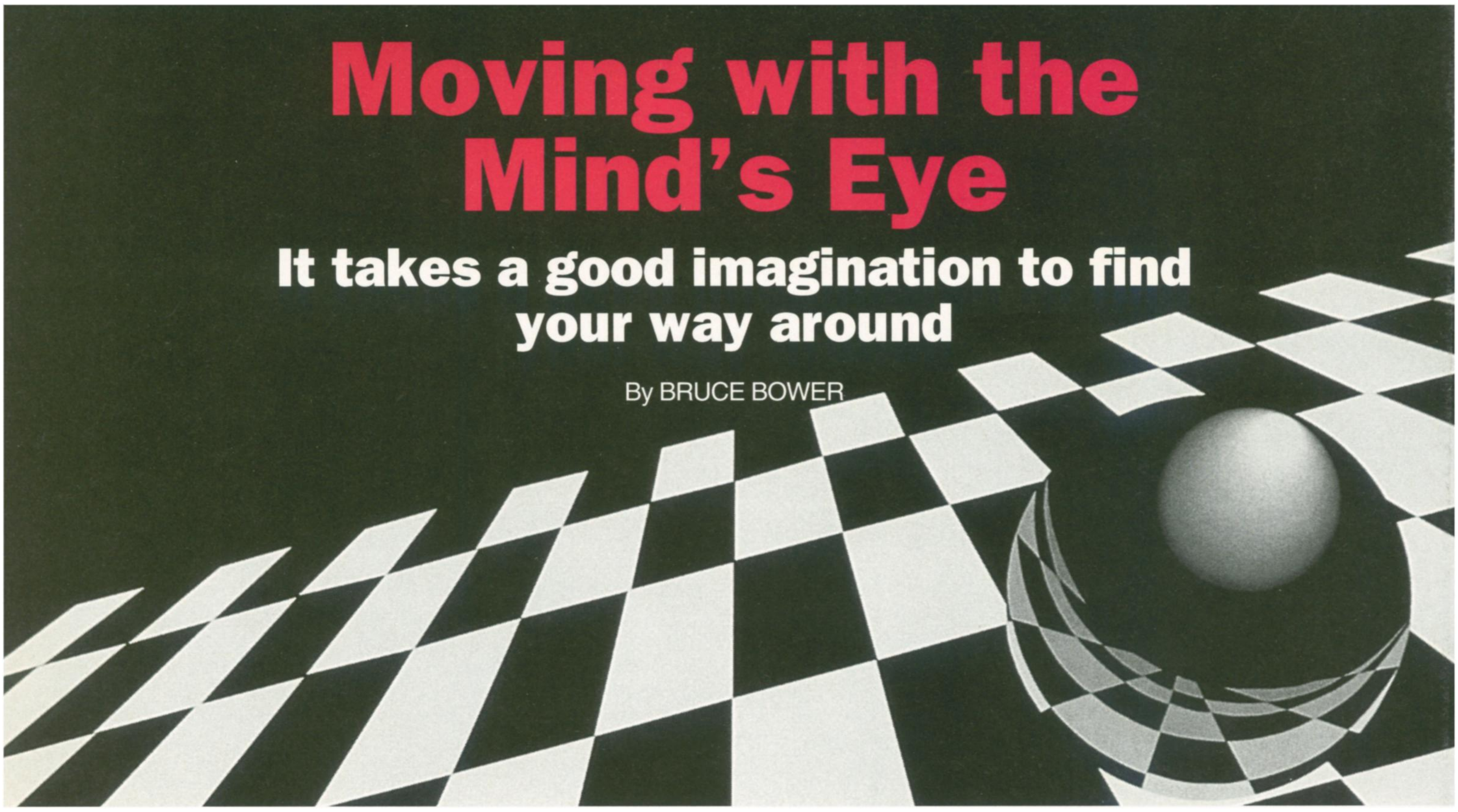
Moving with the Mind's Eye

It takes a good imagination to find your way around

By BRUCE BOWER



A 9-year-old soccer player scoots down the field, receives a pass from a teammate, and boots the ball past the opposing goalie's outstretched arms.

A hiker standing at the edge of a narrow stream squints into a head wind, shouts to her companions on the other side of the current, throws her backpack to them, then hurdles the stream.

A shopper on her way to a department store plans the most efficient route from linens to women's shoes to kitchenware.

Routine accomplishments such as these rarely attract the attention of behavioral scientists. But when researchers look beneath the surface of what it takes to get from point A to point B, the realm of thought best known as the mind's eye is revealed as an essential navigational instrument. According to several new studies, people rely on a disciplined imagination as much as on supple muscles and keen senses to perform skilled actions and arrive at desired destinations.

Mental knowledge of the three-dimensional structure of the external world, also known as mental imagery, may stand at the crossroads of perception, memory, and movement, assert some investigators. Of course, actions depend on accurate perceptions of one's surroundings and physical location in space. But objects often leave the field of vision or get blocked from sight as an individual moves about. The brain picks up the slack by transforming sensory input into a reliable simulation of the immediate environment, these scientists theorize.

Thus, simply by getting up in the morning and venturing out into the world, a person triggers constant mental updating of his or her perspectives on remembered features of the environment. Mental imagery may have evolved primarily as a device for coordinating what we sense, do, and remember, the researchers propose.

"There is now good evidence that perception, action, and mental imagery are linked together closely, even in kids as young as 3 years old," contends John J. Rieser, a psychologist at Vanderbilt University in Nashville. "And I believe that the same applies to infants."

So in the examples above, the soccer player uses his knowledge of a kicked ball's speed and trajectory, as well as the layout of the field, to intercept the checkered sphere at an opportune spot without having to watch its entire flight. The backpacker calculates the force and direction of a jump into the wind on the basis of her memory of physical sensations associated with prior leaps. And the shopper calls to mind the store's labyrinthine layout by taking an imaginary walk through the emporium.

Scientific interest in mental imagery extends back at least 100 years. At that time, psychologist William James and others argued that mental images arise when secondary visual centers in the brain project information back to primary visual centers, which initially decode what the eyes see. However, behaviorism's emphasis on measuring only observable actions dampened interest in imagery research throughout the first half of this century.

In the 1970s, cognitive psychologists treated the mind as if it were a complex computer program that carried out operations with behavioral consequences. But controversy arose over whether mental imagery consists of "pictures in the head" or linguistic interpretations of experience that may seem visual in retrospect.

A set of studies directed by psychologist Stephen M. Kosslyn of Harvard University indicated that mental imagery and vision indeed share key qualities. While keeping their eyes closed, volunteers reported shifting their mental gaze over imagined objects to glimpse various features of the items. Moving from the tail to the head of an imagined horse, for instance, took participants longer than moving from the neck to the head. If told to imagine an object as extremely small or at a distance, participants typically noted that they had to "zoom in" mentally to pick up details of the item. And the edges of imagined objects tended to blur when volunteers looked at them from too close a vantage point (such as imagining an elephant standing a few feet away).

Advances in brain-imaging technology over the past decade have enabled investigators to trace links between cerebral mechanisms employed for seeing objects and for imagining what objects look like. A positron emission tomography (PET) study directed by Kosslyn, published in the summer 1993 Journal of Cognitive Neuroscience, suggested that mental imagery and vision jog similar regions of the brain.

When volunteers closed their eyes and imagined tiny letters of the alphabet, blood flow jumped solely in the part of the primary visual cortex that handles information from the center of the eye. In contrast, when volunteers imagined large letters that would take up much of the visual field, blood flow surged in a nearby area reserved for peripheral visual input.

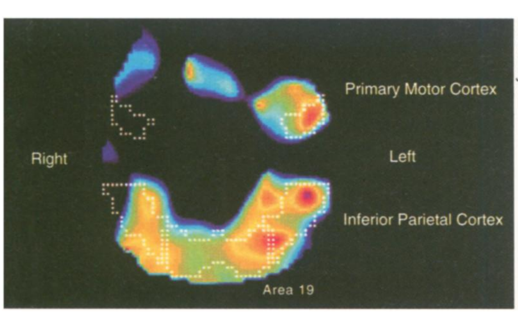
A study in the June 23 SCIENCE plumbs further the relationship between mental imagery and vision. Psychologists know that volunteers can correctly identify a computer-generated target more quickly when it is flanked by two contrasting figures, which researchers refer to as masks. This visual enhancement lasts for up to 5 minutes after the masks disappear if observers simply imagine that the masks are still present, report Alumit Ishai and Dov Sagi, both neuroscientists at the Weizmann Institute of Science in Rehovot, Israel.

Imaginary masks draw their perceptual punch from a kind of low-level visual processing, according to Ishai and Sagi. When observers imagined the masks aligned at a different angle than in initial trials or looked at masks with one eye covered and mentally revived them with the other eye covered, imagery lost its ability to boost visual recognition of the target.

"Sensory traces" of a perception apparently get stored as memories for several minutes, during which they can be recruited by brain areas responsible for producing mental images, the researchers assert.

Studies of people who sit quietly and imagine horses or two-dimensional figures offer few clues as to why the brain bothers to churn out mental imagery in the first place. When scientists examine people as they move around, either in real or imaginary circumstances, internal renditions of sensory experiences start to show their practical bent.

"Cognition is not a disembodied process," asserts Jack M. Loomis, a psychologist at the University of California, Santa Barbara. "Mental representations make it possible to update what has been seen and to sense the body's movement through space."



S. Kosslyn

PET image shows brain areas, in orange and red, most activated when volunteers imagine a partly obscured letter that they have just seen.

The brain takes in a potpourri of sensory cues that arise during movement and weaves them into a "spatial memory" of the body's speed, position, and direction, argues Alain Berthoz, a psychologist at the College of France–National Center of Scientific Research in Paris. People transported a short way while unable to see or hear exploit this capacity to track the speed and distance traveled with remarkable accuracy, Berthoz and his coworkers report in the July 7 SCIENCE. Like some other animals, humans possess an ability to retrace short journeys that qualifies as a kind of homing instinct, they conclude.

The French scientists studied 12 adults, each of whom practiced driving an open, four-wheeled robotic vehicle. Manipulation of a joystick altered the machine's speed as it moved forward down a long corridor. Participants then kept their hands off the controls and in a series of trials were transported down the corridor by remote control, covering distances of 6 1/2 feet to more than 33 feet. Eye goggles rendered riders sightless, and headphones blocked out external noises during these trips.

An investigator tapped volunteers on the shoulder when the vehicle stopped, a signal for them to take control of the joystick again and attempt to drive the same distance the vehicle had just covered.

Not only did participants routinely reproduce distances to within a few inches of perfection, but they drove the robot at nearly the same speed that it had traveled while under remote control. Whether the robot had gradually increased its speed on the first half of its journey and eased its pace the rest of the way, or had quickly accelerated and held a peak speed until it abruptly slowed down near its destination, drivers faithfully duplicated the original speed pattern—even though no instructions had been given to pay any attention to the vehicle's velocity.

As volunteers learned to use the robot's joystick, Berthoz contends, they probably linked all sorts of sensory cues, such as pressure on the back and vehicle vibrations, to the visual perception of velocity. Both visual and nonvisual cues enable the brain to keep tabs on the distance, speed, and direction the body travels, at least for a short time, he theorizes.

Such findings come as no surprise to Loomis. He has directed studies in which people first stand in an open field and look briefly at an object placed up to 40 feet away. Then, walking blindfolded, they end up an average of 22 inches from the object's location, or manage to point continuously toward it while following paths that veer off to the side of the object.

People born blind, as well as those who become blind later in life, display spatial navigation skills nearly equal to those of sighted adults, Loomis and his coworkers report in the February 1993 JOURNAL OF EXPERIMENTAL PSYCHOLOGY: GENERAL. Blindfolded people in each of these three categories achieved roughly the same success at learning and remembering the positions of six different objects placed in a large, darkened room, the researchers noted.

Participants were guided to the objects and told their names until they could reliably point to each item after returning to a starting position. They were then asked to point to specific objects from various positions in the room and to point to objects while imagining that they stood at a previously held position.

Further studies of sighted and blind individuals will address whether a lack of early visual experience undermines the ability to compose a mental map of one's immediate environment, Loomis says.

Ordinarily, sighted people automatically register the way sensations caused by body motion change as they move about, Rieser contends. When walking without vision, they use these learned associations to construct mental updates of their position in space relative to their remembered surroundings, much as Berthoz's riders did on their robotic vehicles.

Accurately scaled mental portrayals of physical surroundings help people to adjust rapidly the force and direction of their walking, turning, and throwing as circumstances change, Rieser and his colleagues report in the June JOURNAL OF EXPERIMENTAL PSYCHOLOGY: HUMAN PERCEPTION AND PERFORMANCE.

Practice in fine-tuning one action to fit a situation automatically fine-tunes other actions that serve the same goal, they theorize. So practice at jumping across streams from a standstill, for instance, would aid all variations on hurdling an obstacle, such as jumping with a running start or one-legged jumping; practice at throwing a ball to a target site would facilitate throwing the object different distances, in different ways (underhand or overhand), and would even transfer to kicking it accurately.

In one experiment, college students walked on a motor-driven treadmill towed through an empty parking lot by a small tractor. In some trials, the treadmill pace was faster than the towing speed; in others, the treadmill pace was slower than the towing speed. Before and after their experience, participants looked at a researcher standing about 26 feet away, pulled down a blindfold and put on sound-blocking earphones, and attempted to walk to the researcher.

The treadmill towing exercise created a mismatch between rate of body motion and progression through an environment, such as occurs in real-life situations when people walk on a moving train or on a moving walkway between airline terminals.

Few participants made errors in walking to the previewed position before mounting the treadmill, Rieser's group reports. But students whose walking speed on the treadmill outpaced the tractor's speed across the parking lot later walked significantly beyond the experimenter's position when blindfolded. What's more, these students felt as if they had walked a shorter distance at a slower rate than on their first blindfolded journey to the same destination.

Conversely, those who walked at a slower treadmill than tractor speed ambled only part of the way to the experimenter's position before stopping. Yet they perceived themselves as striding more quickly and covering a greater distance on the second blindfolded journey.

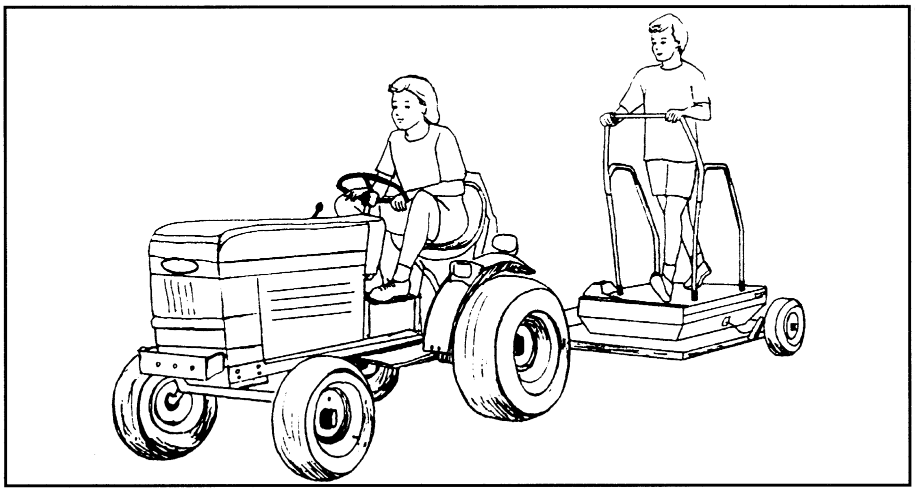
The treadmill tests caused volunteers to change the way they calibrated their walking speed relative to their surroundings, Rieser argues.

After further trials in which treadmill speed exceeded tractor speed, volunteers went beyond a previewed position not only when walking directly toward it, but also when asked to side-step to it. Adjustments in the force and direction of a particular action apparently extend to other actions that serve the same goal, the Vanderbilt scientist says.

Rieser and his colleagues designed similar experiments in which they induced students to change the force and trajectory of a bean bag tossed to a target spot. If towed away from the target during practice sessions, volunteers tossed the bean bag far beyond the target when standing still; if towed toward the target during practice, they threw too short.

In turning-in-place trials, students grasped a waist-high T-bar that rotated at a constant speed in one direction while they stood on a disk that rotated at a faster speed in the opposite direction. Their goal: Step sideways at a rate that kept their hips parallel to the T-bar. After these trials, blindfolded participants consistently turned in place too far to complete what they perceived as a full circle.

Physical activity can even prompt preschoolers to call to mind, on demand, shifting perspectives in a familiar but faraway place, Rieser argues. His contention contrasts sharply with more than 20 years of research that have consistently charted the failure of children to imagine new orientations for printed letters or stationary objects. Many investigators have concluded that children lack the imaginative dexterity of adults.


J. Rieser

People change the rate at which they walk toward a target after striding on a treadmill towed by a tractor.

Rieser's team took a different approach. Across six experiments, they asked 66 children, age 2 to 9, and six of their parents to imagine each child's preschool classroom and assume specific observation points in the classroom. Testing occurred in children's homes.

Children imagined, for instance, that they stood either at their own seat or at their teacher's seat and pointed at objects in the classroom, such as a bookcase and a doorway. Then, youngsters imagined walking from their seat to the teacher's seat while physically walking a path that resembled the one they would take in class. Each wore a blindfold and sound-blocking earphones during this exercise; an investigator kept a steadying hand on children while they walked anywhere from 4 to 8 feet (which compressed the actual classroom distance that would have been traveled). They then pointed to classroom objects.

Another trial required participants to imagine walking from their seat to the teacher's seat while remaining still. Imagination-only trials were run first for half of the children; the rest completed physical walking trials first.

Children age 3 1/2 years and older, like the adults, rapidly and accurately pointed out items after taking a physical walk that corresponded to the imagined classroom layout, Rieser and his coworkers report in the October 1994 CHILD DEVELOPMENT. Children of all ages usually judged their perspective incorrectly after taking an imagination-only walk; adults responded accurately but much more slowly than after an actual walking trial.

Although 2- to 3-1/2-year-olds did poorly on all trials, Rieser had previously found that 2-year-olds can maintain their orientation relative to current surroundings when walking blindfolded. Toddlers may stumble when asked to call to mind knowledge about environments encountered the day or the week before, he suggests.

By about that age, however, children already keep mental tabs on how objects change in perspective when physically manipulated, according to an unpublished study by Rieser and his coworkers. Young children's mental transformations of actual or imagined objects occur quickly and accurately when they are accompanied by corresponding hand movements, even if the movements cannot be seen, the researchers maintain.

A group of children age 2-1/2 to 5 played a game devised by Rieser's team in which they studied a two-headed wooden spoon with one side painted red, the other green. In a darkened room, a researcher then guided their hands in two simple manipulations of the spoon; one ended with the red and green sides in their original positions; the other ended with their positions reversed. After each physical procedure, children were asked to kiss the red spoon. The youngsters succeeded on more than 9 out of 10 attempts.

The brain helps to forge the bond between action and mental imagery, contends Kosslyn. In an unpublished PET study, he found that blood flow in muscle-control areas of the brain jumped when volunteers mentally rotated and compared pairs of illustrated hands. In this case, mental rotation of the pictures may hinge on knowledge about the changing orientation of one's own hands when moving them, Kosslyn suggests.

Further unpublished PET data reveal elevated activity in the motor cortex when participants attempt to identify a briefly presented, partially drawn letter. This finding may reflect the mental insertion of missing letter segments or an internal drawing out of the entire letter, according to Kosslyn.

Whatever direction mental imagery research takes from here, researchers can extract inspiration from the subtitle of one of John Rieser's articles: "It's not being there that counts, it's what one has in mind." □