system in which they might spend time and energy studying and improving teaching."

Stigler and Hiebert also caution against interpreting the video findings too broadly. Japan's high scores on TIMSS might derive from other factors, they say, including extensive preparation for high school entrance exams. And German students did roughly the same as U.S. students on the TIMSS tests despite differences in pedagogy. "This is a study with a sample size of just three countries," says Stigler. "We should be careful not to say that particular teaching practices produce high student learning."

But educators are hoping to draw exactly those types of conclusions from a much larger project already under way. Stigler's research team and collaborators in six other countries are videotaping hundreds of eighth-grade math and science classes. The results, due out in 2001, are likely to produce more painful introspection for U.S. educators.

–STEVE OLSON

Steve Olson writes from Washington, D.C.

NEUROBIOLOGY

Memory for Order Found In the Motor Cortex

Every time we kick a ball, shake a hand, or spoon ice cream to our lips, we rely on a strip of tissue on the top of the brain known as the motor cortex to tell our muscles what to do. Now it appears that the motor cortex can do far more than simply orchestrate movements. On page 1752, a team led by neuroscientist Apostolos Georgopoulos of the University of Minnesota in Minneapolis and the Veterans Affairs Medical Center there reports that neurons in the motor cortex can also do a kind of thinking: They can help recognize and remember the sequence of events in time, at least as a prelude to movement.

If the findings hold up, researchers may have to rethink their view of the motor cortex, and perhaps of other brain regions, too, says Steven Wise, a neuroscientist at the National Institute of Mental Health (NIMH) in Poolesville, Maryland. The work, which Wise describes as "unprecedented," may mean, he says, "that the information needed to perform complex cognitive tasks is distributed very widely" in the brain. In that event, prospects for recovering from brain injuries may someday be brighter. If healthy areas share some functions of the damaged brain areas, Wise speculates, clinicians may be able to boost those functions and stimulate more complete recovery.

The new findings extend more than 2 decades of experiments indicating that in certain circumstances neurons in the motor cortex are active even when an animal isn't moving. In 1976, for example, Jun Tanji and Ed Evarts, then at NIMH, found activity in this region when an animal was preparing to move but not yet moving. And in the 1980s and early 1990s, Georgopoulos's team found that neuronal activity in the motor cortex can provide information about the direction of an upcoming movement and can also serve as a memory for the spatial locations of individual stimuli to which the animal was supposed to move.

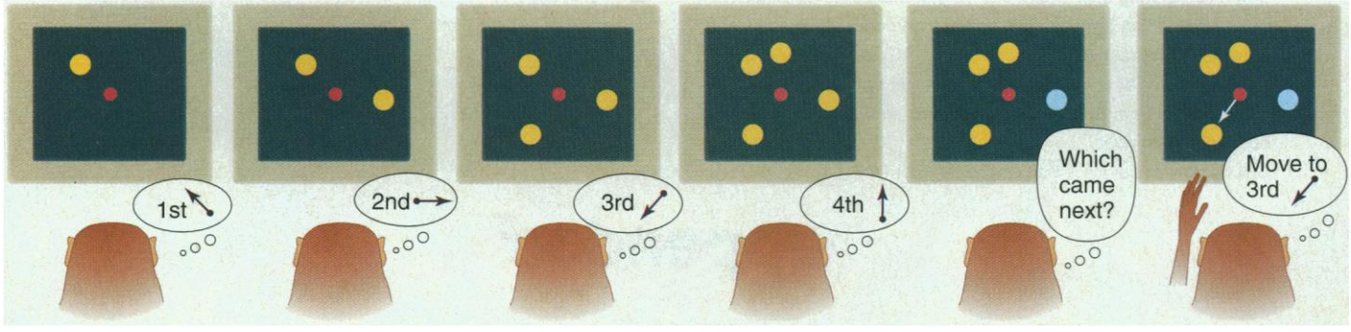
> **"What is truly impressive is the magnitude and robustness of the effect."**
>
> **—Patricia Goldman-Rakic**

Georgopoulos then wondered whether motor cortex cells also could keep track of several spatial locations when they are presented in a sequence. So in 1993, with the aid of his grad student Adam Carpenter and a Minnesota colleague, neuroscientist Giuseppe Pellizzer, Georgopoulos began training a monkey on a task that requires memorizing the order of events in time. The monkey watched a series of yellow spots pop up on a screen in a random order around an invisible circle. Then, after three or four of them were present on the screen, one spot would turn blue. The monkey's job was to move a cursor to the spot that had appeared right after the blue spot. It took a year and a half for the monkey to master the task, and when it did, the team spent an incredible 3 years training a second monkey to do it with up to five spots.

As the monkeys performed their task, the researchers recorded the responses of hundreds of neurons in the animals' motor cortices and found, as expected, that many of them showed a change in activity while the monkey was watching the spots, before any movement occurred. But they were surprised to discover that hardly any of these responses was specifically related to a spot's location. Instead, the researchers found that more than one-third of the recorded neurons showed an abrupt increase in firing only when a spot arrived in a certain place in the sequence—first, say, or second—no matter what its location. These neurons seemed to be specifically sensitive to "serial position."

"What is truly impressive is the magnitude and robustness of the effect," comments Patricia Goldman-Rakic, a Yale University neuroscientist. "Serial position is represented at least as prominently as movement direction." No single neuron could indicate a spot's serial position with certainty. But the more neurons monitored, the better their aggregate responses could specify this position, and the pattern of activity of 16 cells or more could pinpoint a spot's serial position with 100% accuracy, Georgopoulos says.

The data suggest that the motor cortex can play an active role in processing abstract information and is not simply a slave of cognitive regions that tell it what movements to direct. Georgopoulos emphasizes, however, that the region does not do this job alone, but in concert with the rest of the brain. Neurons in the motor cortex, he says, are "participants in a dynamically changing network" of cells in different brain regions that share whatever



SOURCE: GEORGOPOULOS *ET AL.*; ILLUSTRATION: P. MORRIGHAN

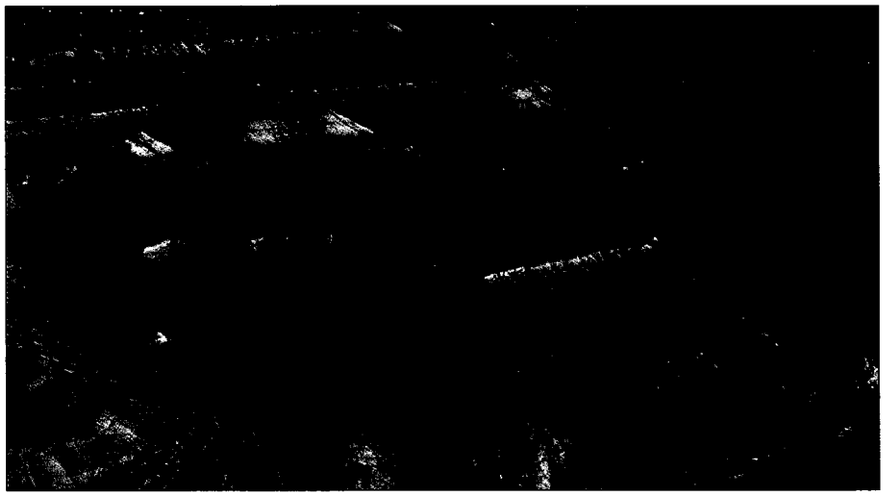
Monkey see, monkey remember. In this task, the monkey has to remember and point to the spot that appeared just after the one that turned blue.

cognitive duties are demanded by a task.

Because of the wealth of evidence showing that the motor cortex is an engine of movement, some neuroscientists are skeptical of these conclusions. For instance, some think it's possible, despite the Minnesota team's results, that the neural responses seen in the study somehow correspond to a monkey's thoughts of moving in the direction of each new spot. To address that concern, says Carl Olson, a neuroscientist at Carnegie Mellon University in Pittsburgh, he would like to see how neurons in the motor cortex respond during a task in which the monkey must remember order, but doesn't ever have to move toward any of the remembered stimuli.

Georgopoulos argues, however, that if the monkey were thinking about moving toward the spots, the neural responses would have been linked to location, not serial position. Still, he agrees that the results are a surprise and says he and his co-workers did a lot of "soul-searching" over the data. It goes to show, he says, that "we hardly know anything about the brain."

–INGRID WICKELGREN



CREDIT: BLM

A rock and a hard place. Geoscientists worry about restrictions on excavating fossil-rich formations such as the Chinle Badlands.

GRAND STAIRCASE MONUMENT

Proposed Access Rules Split Community

Conceived in controversy, the Grand Staircase–Escalante National Monument in southern Utah is the largest U.S. reserve ever created specifically for science. Now, 3 years after President Bill Clinton set it aside, the vast preserve continues to be a flash point, as scientists take sides over a draft plan to preserve its scientific treasures without damaging them.

Clinton enraged state politicians—and surprised researchers—in 1996 when he abruptly set aside the 770,000 hectares of spectacular canyon-carved desert for scientific research. Although critics accused Clinton of pandering to environmental activists, White House officials said the move was the best way to head off a coal mine that threatened the area's fossil-rich rock formations, archaeological sites, and rare ecosystems. Now, the government has upset some scientists as well with a proposal that could limit access to the monument.

Last November, the Bureau of Land Management (BLM) unveiled a draft plan* to close roads and limit routine excavations within the preserve, which lies in a remote area in southern Utah. Ecologists and archaeologists are cautiously praising the plan, but some geologists and paleontologists say that the restrictions will hamper their ability to carry out research. The plan is open for public comments until 15 March, and BLM has been getting an earful.

The rugged region was one of the last places in the continental United States to be mapped. In naming the reserve, Clinton paid tribute to pioneering geologist Clarence Dutton, who in 1880 described the area's terraced cliffs as a "grand staircase" for researchers to climb back into geologic time. Clinton also touted the reserve's "exemplary opportunities for geologists, paleontologists, archaeologists, historians, and biologists." And he gave BLM the tough job of balancing protection and use of the monument, setting a September deadline for a management plan.

The draft plan offers five options. Under its "preferred alternative," BLM would close roughly half of the monument's 3500 kilometers of paved and dirt roads, ban cross-country trips on all-terrain vehicles, and discourage surface-disturbing research on about 60% of the reserve. In the restricted zone, digs would be permitted only to study "unique" or "extremely high value" fossils, artifacts, and rock formations. The plan would also require research permits, with proposals that the monument's managers deem controversial—such as major digs in the restricted zones—subject to review by an independent scientific advisory panel.

Those suggestions have worried some geoscientists. Cracking down on motorized access and surface-disturbing research "could cause some great difficulties" for fossil researchers, says vertebrate paleontologist Jeffrey Eaton of Weber State University in Ogden, Utah, who notes that field studies often require sifting tons of soil for tiny fossil fragments. Adds paleontologist David Gillette of the Museum of Northern Arizona in Flagstaff, "It's just not practical to hike into every site, and you sometimes need heavy equipment." Although Gillette hopes for "flexibility" in the permit system, he worries that the science advisory board may "open the door to needless bureaucracy."

Some geologists interested in studying the monument's oil and coal formations are more critical. The disturbance restrictions "are ludicrous" for large studies, says Utah State Geologist Lee Allison, who is attempting to rally opposition to the plan. If adopted, he says, the rules "would lead me to do science anywhere but there."

But monument chief Jerry Meredith says the BLM's intent is not to prohibit any research. "It would just require some projects to pass a higher test," he says. "Our responsibility is to first protect and preserve these resources—and then allow responsible study."

Archaeologists applaud the "preserve first" attitude. They say unregulated visitation represents the greatest threat to the monument's 2800 known rock art sites and ancient Anasazi dwellings, which date back 1000 years. Biologists and environmentalists are also supporting the restrictions as a way to provide a rare opportunity to study large tracts of undisturbed land. "We don't need roads open just so someone can remove rocks," says soils biologist Jayne Belnap of the U.S. Geological Survey in Moab, Utah. Indeed, the Wilderness Society would like to see more of the monument closed off. "Scientific research should be welcomed, but the monument's remote, unspoiled character should not be sacrificed to promote it," says Greg Applet of the group's Park City, Utah, office.

Meredith has already received more than 6000 comments, which will be analyzed in preparation for the final guidelines this fall. "I know paleontologists aren't excited about packing in backhoes on their backs," he says. But, so far, he isn't promising to put them in the driver's seat.

–DAVID MALAKOFF

* www.ut.blm.gov/monument