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Predicting movement: Crowds of neurons point the way

By looking at how ensembles of neurons fire, scientists can now foresee the direction of limb movements. A group of neuroscientists at the Johns Hopkins University School of Medicine in Baltimore has developed a mathematical model of neural activity that they say enables them to predict the direction in which a monkey will move its arm.

Apostolos Georgopoulos, Ronald Kettner and Andrew Schwartz used an electrode far finer than a human hair to eavesdrop on the activities of neurons in monkeys' motor cortices. The scientists measured how the firing rates of neurons vary with arm movements in different directions, reporting their results in the Sept. 26 SCIENCE. In keeping with earlier studies, they found the behavior of individual neurons to suggest the general, not the specific, direction of arm movements. But the researchers found that the collective activity of a neuronal population acts as a signature for the specific direction of an associated movement.

To make this signature legible, the scientists first determined the "preferred directions" of 224 individual neurons in the arm sector of the monkey's motor cortex. Monkeys trained to push red buttons that had been lit were placed in front of a nine-button, box-shaped array. Starting from a central button, the monkeys reached toward that corner of the box at which there was a lit button. In each trial the monkey reached in one of eight possible directions while an electrode recorded the firing rate of a neuron in the motor cortex. The preferred direction of a neuron is that direction of arm movement in which the neuron fires fastest.

With the preferred directions of the 224 individual neurons in hand, the researchers wanted to combine this information in a way that would highlight how the entire population of neurons relates to the direction of arm movement. To make this possible, Kettner says, he and his co-workers assumed they would observe the same neuronal behavior if they could monitor all 224 neurons simultaneously, a technical ability now beyond the state of the art.

To do the population analysis, the researchers represented each neuron as a vector, or arrow, pointing in the neuron's preferred direction. The length of the arrow depended on the how fast the neuron fired in a given direction of movement. Summing the individual vectors corresponding to each of the 224 neurons yielded a single resultant or "population vector" that represents the collective action of the neuronal ensemble.

Because the model describes how the activity of neuronal ensembles relates to movement, Georgopoulos says it is better able to explain the connection between brain activity and movement than are models relying on the activity of one or a few cells. And compared with other models that are strictly theoretical, he says, his model reflects more realistically the neuronal process he and his colleagues observe.

When the scientists also represented the direction of the actual arm movement as a single vector called a movement vector, they found agreement between the direction of this vector and that of the population vector. They say their study shows how populations of neurons may embody the directional information required for such feats as reaching for an object. Deliberate movements such as the monkey's arm movements are only one instance in which neuronal populations reflect directional information, the researchers say. Fine eye movements, the direction of head tilt and the direction of moving visual stimuli are others. The scientists suggest also that population vectors can be a tool for studying brain events occurring during the planning that precedes actual movements — that is, for studying "thinking" about moving.

— I. Amato

Biological diversity: Going . . . going . . .?

Human beings are destroying the biological diversity of the planet with the carelessly grand gestures of a monarch or a maniac, according to Harvard University biologist Edward O. Wilson. But it's nothing personal. We don't know the species we're destroying; we don't even know how many species there are — 5 million? 50 million?

Nonetheless, Wilson said in the opening address of this week's National Forum on BioDiversity, the current extinction crisis is shaping up as the worst in 65 million years. It "seems destined to approach that of the great natural catastrophes at the end of the Paleozoic and Mesozoic eras," he said. And a small group of prominent scientists, including Wilson, took advantage of the occasion to announce their belief that the extreme and accelerating loss of species diversity poses a threat to civilization second only to nuclear war.

The group, called Club of Earth, hopes to provide an ecological counterweight in policy decisions, according to member Paul Ehrlich of Stanford University. Its formation was prompted in part by a National Academy of Sciences report this year that took a decidedly moderate view of the perils of population growth (SN:3/15/86,p.167). "A lot of the statements were ecologically absurd," Ehrlich says. Unless ecological sustainability is valued along with economic development, he warns, the consequences will be catastrophic.

The luxuriance of life in tropical rain forests — and the paucity of our understanding as we put that diversity at risk — took center stage the first day of the conference, held by the academy and the Smithsonian Institution. Rain forests cover only 7 percent of the land surface of the earth, yet they contain more than half of the earth's species. Says Wilson, "From a single leguminous tree in the Tambopata Reserve of Peru, I recently recovered 43 species of ants, belonging to 26 genera — about equal to the entire ant fauna of the British Isles."

Most of the world's species are still unknown and uncategorized, according to Wilson. Only about 1.7 million species have been described; the work of Terry Erwin of the National Museum of Natural History in Washington, D.C., indicates that there may be as many as 50 million species of insects alone.

But the rain forests are being clear-cut (SN:10/4/80,p.218). About 40 percent is already gone, Wilson says, and an area about the size of West Virginia is cleared each year. At that rate, he says, all remaining rain forest will be gone or seriously disturbed by the year 2035. That means the loss of what one researcher calls the "wonder plants of the future" — medicinal plants, fuel plants and an estimated 20,000 food plants to supplement the 20 species on which humans now rely. In a worst-case scenario presented by Ehrlich, the loss of diversity may mean the desertification of the tropics, a worldwide loss of climatic stability and crop failures due to a lack of insect pollinators.

To reverse the trend, some of the conference participants suggest that developed countries — which use more than 80 percent of the world's resources, according to Peter Raven of the Missouri Botanical Gardens in St. Louis — play a much larger part in funding conservation efforts. According to Wilson, it would take about $8 billion to make an impact on tropical deforestation over the next five years. And, so that we know what we risk losing, Wilson proposes a full-scale effort to catalog the species diversity of the planet.

"If we don't move, and real fast," says biologist Daniel Janzen of the University of Pennsylvania in Philadelphia, "your kids won't have it to argue over."

— L. Davis