Researchers discover fundamental rules for how the brain controls movement

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Emma Towlson, Postdoc at the Center for Complex Network Science Research, is an author on a new paper describing for the first time researchers' ability to predict, test, and confirm with unprecedented detail how a nematode's brain controls the way it moves. Credit: Matthew Modoono/Northeastern University

The human brain is a mysterious supercomputer. Billions of neurons buzz within an intricate network that controls our every thought, feeling, and movement. And we've only just begun to understand how it all works.

To conquer the puzzle of the human mind, researchers at Northeastern's Center for Complex Network Research start with simpler models. The brain of a nematode worm, for example, has about 300 neurons and 2,200 synapses.

Using the nematode as one test system, scientists at CCNR have spent the past several years understanding how a network controls itself—for instance, which individual neurons in the worm's brain are in charge of a backward wiggle. And in research published online Wednesday in *Nature*, they describe for the first time their ability to predict, test, and confirm with unprecedented detail how a nematode's brain controls the way it moves.

"I am delighted to have the first direct experimental confirmation of the control principles," said Albert-László Barabási, Robert Gray Dodge Professor of Network Science and University Distinguished Professor of Physics, and director of the Center for Complex Network Research. "And I'm equally excited that it offered us a way to systematically predict, with exceptional accuracy, the neurons that are involved in specific processes."

Researchers in Barabási's lab studied the nematode brain, which has been mapped neuron by neuron, synapse by synapse. They developed a theory to predict precisely what neurons would control specific types of locomotion—the worm's ability to squirm and scoot around. Then, colleagues from the Medical Research Council Laboratory of Molecular Biology in Cambridge, England, tested the predictions by killing individual neurons from the nematode brain with a laser. They then measured the effects of these "microsurgeries" on behavior.

"Remarkably, the predictions were confirmed, supporting the theory and providing new insight into how individual neurons control body movements," said William Schafer, a scientist at the MRC lab who led the laser experiments.

“I think the next sensible steps for us are zebra fish, maybe mouse, and then human,” Towlson said. “The human brain is always the ultimate dream.” Credit: Matthew Modoono/Northeastern University

This is an important first step toward what Emma Towlson, a postdoctoral researcher at CCNR and one of the study's lead authors, calls "the dream." One day, researchers may be able to translate a version of the nematode control model to the human brain. This would be life-changing for patients with cerebral palsy, Lou Gehrig's disease, and other ailments that lead to loss of muscle function.

"We could, in theory, turn something that is uncontrollable into something that is controllable. This is the ultimate ambition, but there is a huge leap in the middle," Towlson said.

To make sense of the nematode brain, Towlson created a map of the connections between neurons and muscles. She was surprised by the relative simplicity of the model, composed of ones and zeros that indicated whether or not there was a connection. Researchers also made a number of assumptions with regard to the biological parameters.

"And it still comes out with this level of prediction," Towlson said. "That amazes me. In my mind, that says we're really getting at something fundamental."

Moving forward, Towlson would like to examine the nematode brain network in more detail. She knows which neurons control which muscles and their corresponding movements. But how much energy and time does one wiggle take compared to another, and does that explain why the worms move in the ways they do?

Towlson also wants to apply the control principles to other models.

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More information: Gang Yan et al. Network control principles predict neuron function in the Caenorhabditis elegans connectome, *Nature*

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