Sensory feedback shapes individuality to provide equal space for behavioral excellence

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Chiel's lab found that while sensory feedback reduced individuality across a group of slugs, the feedback increased variability within individuals. Credit: Mike Sands

We can quickly tell from the way someone walks whether that person is

young or old, male or female, healthy or sick, because patterns of movement vary from one person to the next. In fact, we can often recognize a friend from a distance, even if he's walking with his back to us, because of his characteristic strides.

Scientists have assumed that evolution would push us toward a single "best" method for walking—or for any movement. But even one person's repeated steps, watched closely, are rarely identical.

"Is this variability in walking just noise that the nervous system must overcome, or does it contribute to normal function?" asks Hillel Chiel, a biology professor at Case Western Reserve University.

Chiel worked with Case Western Reserve's Miranda J. Cullins, Jeffrey McManus, Hui Lu, and Kendrick Shaw, who are recent PhD graduates, and current PhD student Jeffrey Gill to find the answer. Their research, published today (Oct. 1) in the journal *Current Biology*, suggests maintaining variability is essential both for normal behavior and for longer-term evolution.

"Most people see variation as a problem to get away from, but it is the solution," Chiel said. "Our bodies change throughout life, and our nervous system handles variation to enable us to function as things change."

The findings have implications for rehabilitating those who have suffered injuries, debilitating illness or stroke; training athletes; and for building better robots.

Gait and the human nervous and muscular systems that control it are highly complicated, so, to address variability, the researchers investigated swallowing motor patterns in the marine mollusk Aplysia californica. This sea slug is known for its large, identified neurons,

which have been used to understand cellular and molecular mechanisms of learning and motivation.

The team looked down to the level of motor neurons. The researchers removed sensory inputs from the slugs and looked at motor patterns in the animal's isolated brain. They found that the motor patterns varied more from one animal to the next than with sensory feedback.

When the sea slug's sensors provide feedback as it feeds, all the slugs responded similarly—that is, it became harder to tell one slug from another just by looking at their motor patterns. Their response ranges were nearly identical when the movement was essential to swallowing, such as how long the feeding grasper was closed as it pulled seaweed into the mouth.

Surprisingly, however, the researchers didn't find that feedback reduced variability within each sea slug. Just the opposite: the range of responses within each animal became broader.

But how does increasing variability within individual animals reduce variability across the group?

"One way to reduce individuality is to give all the animals access to a broader range of responses—a common solution space," Chiel said.

But having a range of options within that space is an advantage in a world that's constantly evolving, Chiel said. "Darwin's big insight was that variation is the raw material that can be used to allow animals to adapt to a changing environment, and thus enhance their fitness."

Changes include those within each individual. A person who suffers a stroke, especially with disruption to sensory feedback, would benefit more from therapy to regain access to the full range of movement

possibilities rather than training him or her to step one way, the researchers said.

For training athletes, skills such as shooting free throws in basketball may improve by narrowing variability in that part of their body that must connect with the ball; but they may need to increase variability in other parts of their body at the same time to take full advantage of their body's special characteristics.

Robots that have a built-in range of responses they can use to automatically adjust to variations in tasks would be more useful than those that must be reprogrammed to handle each change, the researchers said.

Chiel's lab is now looking into whether their observation in sea slugs is relevant to vertebrates, including humans, and investigating cellular and synaptic mechanisms that allow sensory feedback to shape motor variability.

"We think that these results are not unique to slugs, but a general phenomenon for all animals," Chiel said. Research by others lends support and, "We believe it's why we each have a different way of walking - and why our unique individuality is so important for success in what we do."

Provided by Case Western Reserve University