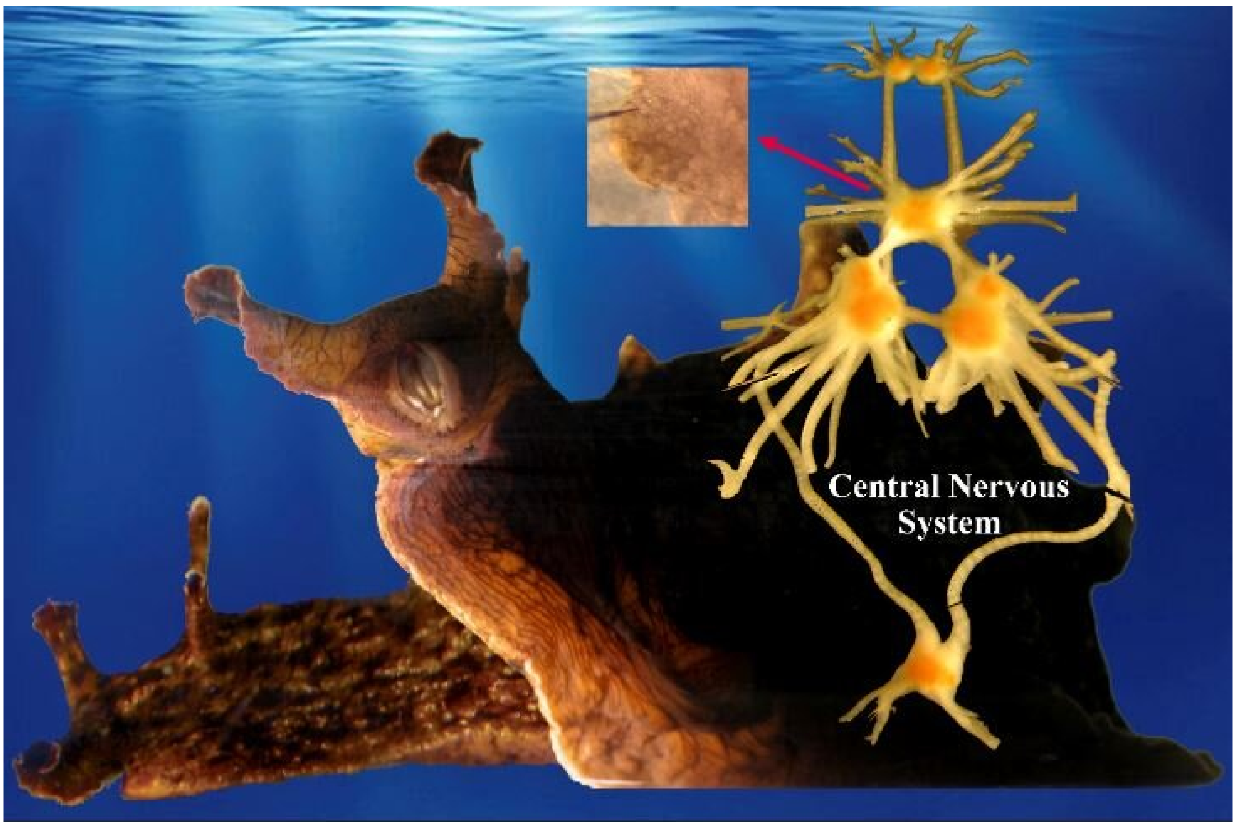
Synaptic variability provides adaptability for rhythmic motor pattern

June 19 2020



Aplysia in motion and in a feeding state, as well as the identified neurons in the central nervous system that control the behaviors. Credit: Jian Jing, Ke Yu

A well-trained athlete sprinting 100 yards performs a highly stereotyped, repetitive motor pattern. Neuroscientists understand that these rhythmic motor programs, such as walking, swimming and running, are produced by neural circuitry that generates repetitive patterns that are similar from cycle to cycle. Over a century ago, spinal cord experiments led to the proposal that a simple neural network can produce such a rhythmic oscillatory firing pattern. These oscillatory networks are now known as central pattern generators.

In analyzing the production of these firing patterns by central pattern generators, neuroscientists have traditionally focused on experimental preparations where the rhythmic output is nearly identical from cycle to cycle. However, for an animal or person to be successful, the motor program must be adaptable. The motor pattern of an individual walking on a wet, slippery surface differs from the motor pattern of an individual walking on a dry, smooth surface. The motor pattern of an individual eating granola with nuts and dried berries differs from the motor pattern of an individual eating plain oatmeal.

Generating variable motor programs is also essential to enable future learning. During development, a child learns to produce a mature motor pattern by beginning with a highly variable pattern. Early on, a toddler's walking is very unstable, but before long, they can walk with a consistent gait. The same process goes on when an older individual learns a new activity, such as swimming or ice skating. Gradually, the nervous system comes to consistently produce a more successful motor program. Birds that learn song go through a similar progression—early on, the song is variable, but gradually, it becomes more stereotyped or consistent.

How does the nervous system generate variable motor programs? Recently, researchers at Nanjing University in Nanjing and Peng Cheng Laboratory in Shenzhen, in collaboration with colleagues at Mount Sinai in New York, studied the motor program for feeding in the simple nervous system of the marine snail Aplysia. These investigators identified an important fundamental mechanism by which variability in the strength of excitatory inputs to the feeding central pattern generator results in flexibility in the feeding motor program. When one neuron provides input to another, it often induces an electrical response, i.e., a postsynaptic potential. It has long been recognized that single postsynaptic potentials are generally subthreshold for triggering a postsynaptic response. Furthermore, postsynaptic potential amplitude generally varies substantially over time, even over less than a tenth of a second. Although this might seem suboptimal, the authors demonstrate that under certain conditions, this variability can translate into behavioral flexibility.

The marine snail Aplysia has relatively few nerve cells, and the same individual nerve cells have characteristic properties and can be re-identified from one individual animal to another. Taking advantage of their ability to work with identified neurons, the authors demonstrated that synaptic inputs from either of two upstream identified neurons can drive activity in a pivotal central pattern generator neuron, which has a low level of excitability. The input from one upstream neuron is variable and quite weak and does not always cause the pattern generator neuron to fire. Consequently, motor programs that are induced when this upstream cell is activated are variable. In contrast, although the input from the second upstream neuron is similarly variable, it is substantially stronger. Consequently, the pattern generator neuron is reliably excited and the motor output is much less variable. Thus, whether the circuit produces a stereotyped or a variable pattern is determined by which upstream neuron drives activity. Elegant computational modeling studies reinforced the physiological findings and uncovered additional insights that clarified the specific contributions of synaptic variability and strength to the different degree of motor program variability.

In summary, the authors demonstrate that variability in the synaptic inputs combined with the low level of excitability of the central pattern generator neuron provides the snail with the ability to switch to a more variable behavioral pattern. Future research will reveal whether similar shifts in the variability of motor programs in mammals can be explained by a similar mechanism.

The study is published in *Science Advances*.

More information: "Synaptic mechanisms for motor variability in a feedforward network" *Science Advances* (2020). advances.sciencemag.org/content/6/25/eaba4856

Provided by Nanjing University School of Life Sciences