Medical Xpress

Songbirds provide insight into speech production (w/ Video)

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Bengalese finch. Image: Wikipedia

(PhysOrg.com) -- With the help of a little singing bird, Penn State physicists are gaining insight into how the human brain functions, which may lead to a better understanding of complex vocal behavior, human speech production and ultimately, speech disorders and related diseases.

Dezhe Jin, assistant professor of physics, is looking at how songbirds transmit impulses through nerve cells in the brain to produce a complex behavior, such as singing. Songbirds are particularly well suited for studying speech production and syntax -- the rules of syllable or word sequence -- because there are more similarities between birdsong and human speech than one may initially think.

"We are not only interested in birds," Jin told attendees today (March 18) at the American Physical Society's March meeting in Portland, Ore. "We are ultimately interested in studying how the human brain works and better understanding ourselves."

While many animals communicate vocally, songbirds are among the few that learn their communication sounds in a manner similar to humans. Although human and bird brains are different, researchers believe that both the speech and song learning processes involve similar neural mechanisms.

"It is very hard to do human experiments," said Jin. "So, to conduct these experiments, we use the songbird. Songbirds are much simpler than humans, and have fewer neurons."

Alexay Kozhevnikov, assistant professor of physics, works with Jin to conduct recordings of brain activity that occurs in songbirds during singing. In this way, the songbird's brain acts as a laboratory for understanding neural networking.

Because the major brain components involved in song production are well documented, Jin uses them as a framework for designing computational models. He can test these models against the neural recordings, and eventually determine how the interconnection of these networks leads to syllable production and syntax.

As in human language, birdsong is composed of syllables. However, rather than a random string of syllables, the order follows a complex and variable pattern, which is determined by restriction and flexibility. Restriction states that a certain syllable can only be followed by a specific set of other syllables. However, the syllable that comes next is selected randomly from the possible set, creating the flexibility.

The underlying mechanism for stringing together multiple song syllables is similar to putting words together to form a sentence. Flexibility allows the researchers to focus on how this mechanism determines syllable syntax.

"The similarity between the restriction and flexibility is very solid," said Jin. "You have to be cautious though because people will be tempted to take it too far and assume that the birds are talking."

Jin shows that a particular syllable is encoded in a branching chain network of neurons in the high vocal center (HVC), or "control center" for song production in the brain. The HVC transmits precisely timed impulses, or spikes, to downstream neurons that drive syllable production.

His model of impulse transmission in the brain predicts the syllable sequence statistically will follow a partially observable Markov model. This means that the decision at the branch point is random, and the branch that propagates the signal is chosen independent of events leading up to that point.

A key feature of Jin's model is the winner-take-all mechanism -- when an impulse reaches a branch point within the chain network, the signal will continue on through one branch, while abandoning other potential branches. The syntax of birdsong syllable sequence is governed by the connectivity of the neural networks.

"When the signal is passed on at a branch point, it is an all-or-nothing transmission, in that both branches may sense the signal, but the one that may receive a slightly stronger signal will win out and the impulse will progress down that chain," says Jin.

The similarity between the neural networks in songbirds and humans makes them important for understanding the brain circuitry that underlies speech and language production. The knowledge obtained from analyzing the neural pathways in birdsong can function as a bridge to address and treat speech and language disorders.

Provided by Pennsylvania State University