Artificially cultured brains improve processing of time series data, shows study

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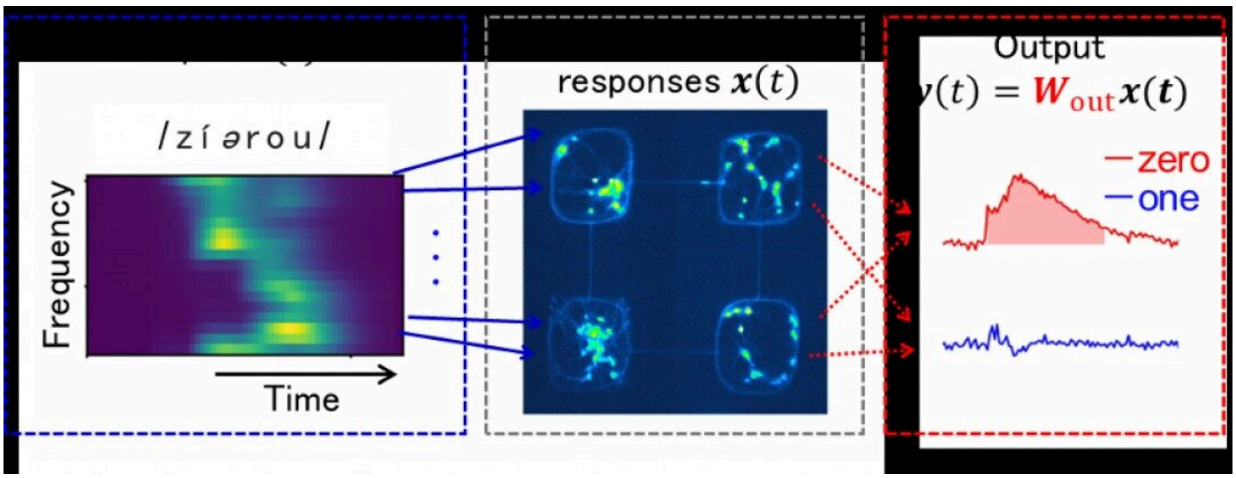


When the artificial cultured brain receives a human speech sound (the number 0 pronounced as "zero" in English) as input, it converts the input into a multicellular response. The response signal is then read out by a linear classifier to achieve classification of the time-series signal. The artificial cultured brain in the figure is designed to grow within four squares connected by thin lines, resembling a modular architecture. In this experiment, we found that such modularity in the artificial cultured brain improves the classification performance. Credit: Yamamoto et al.

The brain comprises billions of interconnected neurons that transmit and process information and allow it to act as a highly sophisticated information processing system. To make it as efficient as possible, the brain develops multiple modules tasked with different functions, like perception and body control. Within a single area, neurons form multiple clusters and function as modules—an important trait that has remained essentially unchanged throughout evolution.

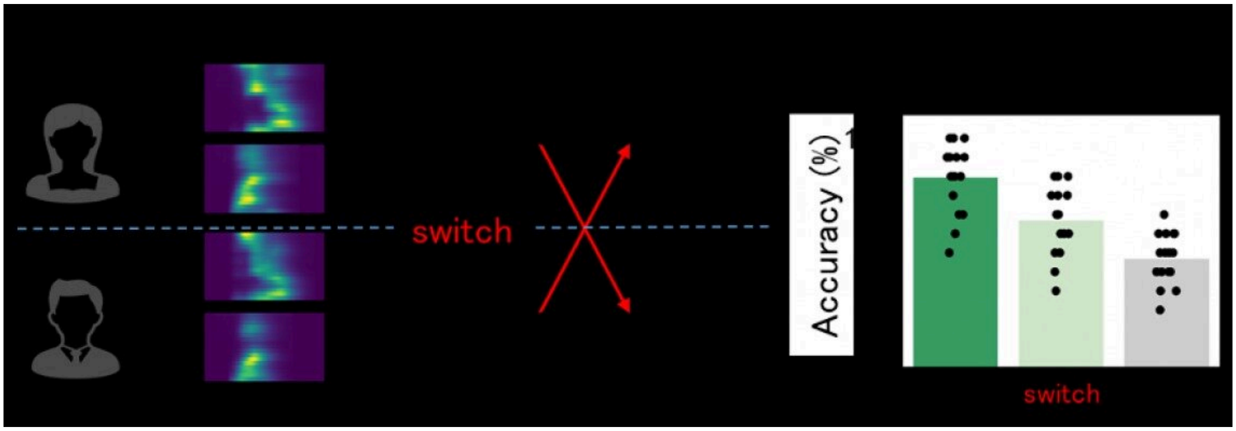
Still, many unanswered questions remain regarding how the specific structure of the brain's network, such as the modular structure, works together with the physical and chemical properties of neurons to process information.

Reservoir computing is a computational model inspired by the brain's powers, where the reservoir comprises a large number of interconnected nodes that transform input signals into a more complex representation.

Now, a research team has developed machine learning based on reservoir computing to analyze the computational capabilities of an "artificially cultured brain" composed of neurons derived from the cerebral cortex of rats, i.e., rat cortical neurons.

The team's findings were published in the *Proceedings of the National Academy of Sciences* on June 12, 2023, and was led by Takuma Sumi, Hideaki Yamamoto, and Ayumi Hirano-Iwata, researchers based at Tohoku University. They worked in collaboration with Yuichi Katori from the Future University Hakodate.

"Using optogenetics and fluorescent calcium imaging, we first recorded the multicellular responses of the cultured neuronal network," said Yamamoto. "Then we decoded it using reservoir computing, finding that the artificial cultured brain possessed a short-term memory of several hundred milliseconds, which could be used to classify time-series data, such as spoken digits."



The reservoir computer based on biological neurons could be used to classify spoken digits even when the speakers were switched during training and testing. Classification accuracy after the switch decreased compared to when there was no speaker switching, but classification was achieved above chance level. Such classification was not possible when the input signal was directly decoded by a linear classifier, suggesting that biological neurons act as a generalization filter to improve the performance of reservoir computing. Credit: Yamamoto et al.

Samples with a higher degree of modularity were found to exhibit better classification performance. Moreover, a model trained on one dataset was able to classify another dataset in the same category, revealing that the artificial cultured brain could filter information to improve the reservoir computing performance.

"The findings advance our mechanistic understanding of information processing within neuronal networks composed of biological neurons and move us toward the potential realization of physical reservoir computers based on biological neurons," adds Yamamoto.

More information: Takuma Sumi et al, Biological neurons act as generalization filters in reservoir computing, *Proceedings of the National*

Academy of Sciences (2023). DOI: 10.1073/pnas.2217008120

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