New tool allows researchers to compare maps of brain connectivity built on different atlases

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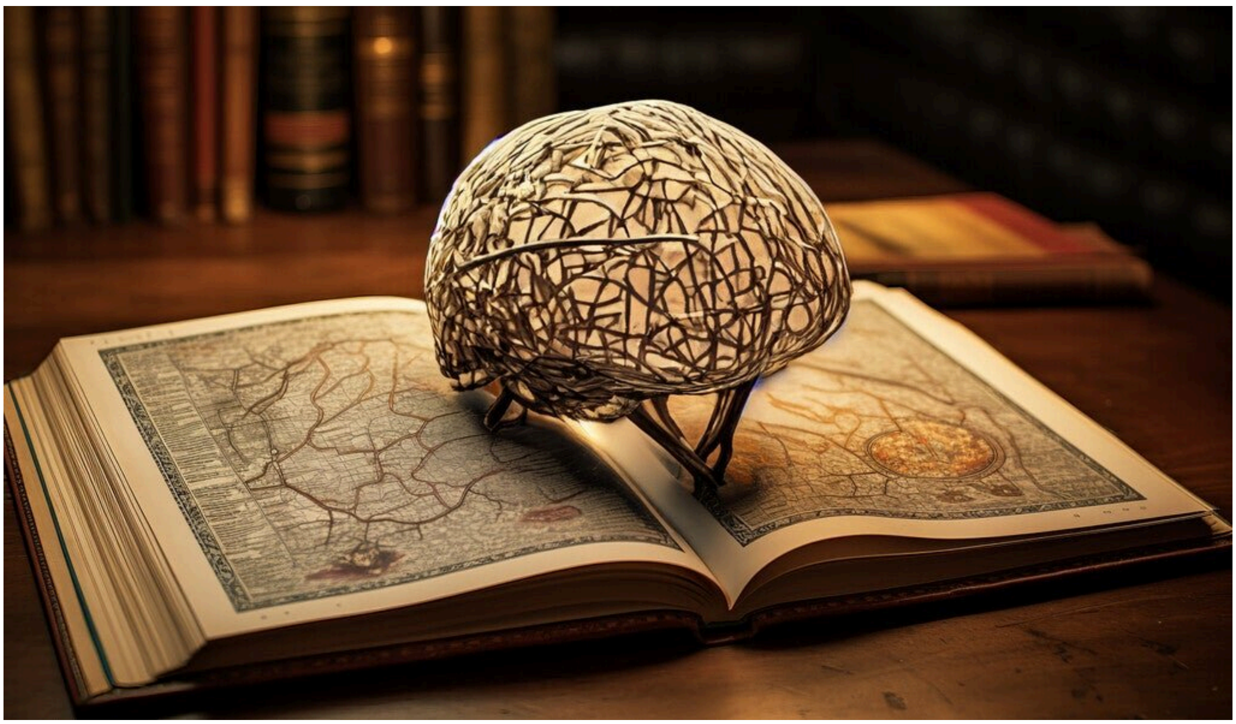

Illustration from generative AI images. Credit: Michael S. Helfenbein/Yale University

The ability to map connections between different regions of the brain has helped scientists better understand the brain's relationship to behavior, how brains differ between people, and how they're affected by disease. These maps, called connectomes, consist of imaging data superimposed on atlases that define the locations and borders of different brain regions. But there are many different versions of brain atlases, and a connectome built on one can't be directly compared to one built on another.

In a new study, Yale researchers have developed a publicly available tool that allows for those comparisons. The new approach, known as Cross Atlas Remapping via Optimal Transport, or CAROT, can transform a connectome built on one atlas into a connectome based on another, enabling researchers to compare connectomes from different studies and reuse them in future analyses. The findings were described June 8 in the journal *Medical Image Analysis*.

Brain atlases divide the brain into different regions, but they don't all do so in the same way, varying in the size, shape, and number of regions. This limits the use of connectomes, said Javid Dadashkarimi, a Ph.D. candidate in the Department of Computer Science at the Yale School of Engineering & Applied Science and lead author of the study.

"Previously, the only solution would be to reprocess raw data using a different atlas, which takes time and requires access to raw data that's not always available," said Dadashkarimi, who conducted the research across two labs: Dustin Scheinost's at Yale School of Medicine and Amin Karbasi's at the School of Engineering & Applied Science.

With CAROT, scientists can take a connectome constructed from one atlas and reconfigure it to conform to another atlas without having to reprocess data. It does so using a mathematical approach known as optimal transport.

One of the first instances in which optimal transport theory was used to solve a real-world problem was during World War II, Dadashkarimi explained.

"During the Second World War, militaries needed to figure out how to distribute soldiers and resources to various camps while minimizing costs, and that turns out to be a very hard question in terms of time complexities," he said. "Mathematician Leonid Kantorovich proposed a very advanced version of optimal transport theory to solve this problem and now it's widely used in other fields."

Similar to how optimal transport was applied to efficiently distribute military resources, CAROT uses optimal transport to determine how to best redistribute data. For instance, if a connectome is based on an atlas that divides the brain into 200 regions, CAROT can essentially remap that data across an atlas with 300 brain regions without fundamentally changing the connectome itself.

For the study, the researchers evaluated how well CAROT-generated connectomes compared to connectomes created directly on atlases. To do so, they first built connectomes on six different atlases based on the same functional magnetic resonance imaging (fMRI) data, then reconstructed each of those connectomes on each of the other five atlases. For example, the connectome built on atlas A was reconstructed on atlases B, C, D, E, and F. The reconstructed connectomes, they found, were similar to the originals. For instance, a connectome transformed from atlas A to atlas B was comparable to the connectome built directly on atlas B.

Further, reconstructed connectomes performed as well as original connectomes when applied to neuroscientific analyses—such as using a connectome to predict IQ—yielding similar insights into brain function, the researchers said.

"Our research shows CAROT can reconstruct connectomes on different brain atlases without altering the makeup of that connectome and without the need for raw data," said Scheinost, associate professor of radiology and biomedical imaging at Yale and senior author of the study. "In essence, it means we can do more with data we already have and gain a better understanding of what all of that data can collectively tell us about the brain."

The researchers have made CAROT available to other scientists. Currently, it can only be applied to connectomes based on fMRI data. However, the team hopes they will be able to expand CAROT's use to other types of brain-based data, such as electroencephalograph, in the future.

More information: Javid Dadashkarimi et al, Cross Atlas Remapping via Optimal Transport (CAROT): Creating connectomes for different atlases when raw data is not available, *Medical Image Analysis* (2023). DOI: 10.1016/j.media.2023.102864

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