

## **Cache Cab: Taxi Drivers' Brains Grow to Navigate London's Streets**

Memorizing 25,000 city streets balloons the hippocampus, but cabbies may pay a hidden fare in cognitive skills

By Ferris Jabr

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Manhattan's midtown streets are arranged in a user-friendly grid. In Paris 20 administrative districts, or arrondissements, form a clockwise spiral around the Seine. But London? A map of its streets looks more like a tangle of yarn that a preschooler glued to construction paper than a metropolis designed with architectural foresight. Yet London's taxi drivers navigate the smoggy snarl with ease, instantaneously calculating the swiftest route between any two points.

These navigational demands stimulate brain development, concludes a study five years in the making. With the new research, scientists can definitively say that London taxi drivers not only have larger-than-average memory centers in their brains, but also that their intensive training is responsible for the growth. Excelling at one form of memory, however, may inhibit another.

Neuroscientist Eleanor Maguire of University College London (U.C.L.) first got the idea to study London cab drivers from research on memory champions of the animal world. Some birds and mammals, such as western scrub jays and squirrels, cache food and dig it up later, which means they must memorize the locations of all their hiding spots. Researchers noticed that a part of the brain called the hippocampus was much larger in these animals than in similar species that did not secret away their snacks. The hippocampus is a seahorse-shaped section in the vertebrate brain that is crucial for long-term memory and spatial navigation.

Maguire wondered whether London taxi drivers also had larger-than-average hippocampi. To earn their licenses, cab drivers in training spend three to four years driving around the city on mopeds, memorizing a labyrinth of 25,000 streets within a 10-kilometer radius of Charing Cross train station, as well as thousands of tourist attractions and hot spots. "The Knowledge," as it is called, is unique to London taxi licensing and involves a series of grueling exams that only about 50 percent of hopefuls pass.

In her earliest studies, Maguire discovered that London taxi drivers had more gray matter in their posterior hippocampi than people who were similar in age, education and intelligence, but who did not drive taxis. In other words, taxi drivers had plumper memory centers than their peers. It seemed that the longer someone had been driving a taxi, the larger his hippocampus, as though the brain expanded to accommodate the cognitive demands of navigating London's streets. But it was also possible that The Knowledge selected for people whose memory centers were larger than average in the first place.

To find out which possibility was more likely, Maguire and her U.C.L. colleague Katherine Woollett decided to follow a group of 79 aspiring taxi drivers for four years to measure the growth of their hippocampi with magnetic resonance imaging (MRI) as they completed The Knowledge. For the sake of comparison, Maguire also measured brain growth in 31 people who did not drive taxis but were of similar age, education and intelligence as the taxi trainees. At the

start of the study, all of the participants had more or less the same size hippocampi. Maguire also made sure that the aspiring cabbies and non-taxi drivers performed similarly on tests of working memory and long-term memory.

Four years later 39 of the 79 trainees had earned their licenses; 20 trainees who failed their exams agreed to continue participating in the study. When Maguire gave the successful and disappointed trainees the same battery of memory tests she had given them at the start of their training, she found that drivers who earned their licenses performed far better than those who failed—even though they had performed equally four years earlier. And MRIs showed that the successful trainees' hippocampi had grown over time.

There are several ways to explain the ballooning hippocampus. The hippocampus may grow new neurons or hippocampal neurons may make more connections with one another. Non-neuronal cells called glial cells, which help support and protect neurons, may also contribute to the increase in hippocampal volume, although they are not generated as quickly as neurons.

The successful trainees did not perform better on all tests of memory, however. Licensed taxi drivers did worse than non-taxi drivers on a test of visual memory called the Rey-Osterrieth Complex Figure Test: The subject is asked to study what looks like a dollhouse designed by a loony architect, full of superfluous lines and squiggles, and sketch it from memory 30 minutes later.

Maguire thinks that The Knowledge may enlarge the hippocampus's posterior (rear) at the expense of its anterior (front), creating a trade-off of cognitive talents—that is, taxi drivers master some forms of memory but become worse at others. In her earlier work, Maguire found evidence that, whereas the rear of the hippocampus was bigger in taxi drivers, the front was usually smaller than average. She didn't find this same difference in her new study because, she speculates, front-end shrinkage may happen after the four years of training. The hippocampus's rear section seems to be important for spatial navigation specifically, but Maguire says the front end's role remains more mysterious.

Maguire says she was "greatly relieved" by the results of her study, which appears in the December issue of *Current Biology*. "We didn't know how long the effects would take to appear on an MRI scan," she says. "Maybe they only appeared quite some time after the trainees qualified. But we found them within the five years it took to do the study."

Neurobiologist Howard Eichenbaum of Boston University commends the study for answering the "chicken-and-egg question" posed by Maguire's earlier research. He sees it as confirmation of the idea that cognitive exercise produces physical changes in the brain. "The initial findings could have been explained by a correlation, that people with big hippocampi become taxi drivers," he says. "But it turns out it really was the training process that caused the growth in the brain. It shows you can produce profound changes in the brain with training. That's a big deal."

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