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What rats in a maze can teach us about our sense of direction

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Just ask a cab driver - they've got that map in their head. Credit: Beverley Goodwin/Flickr, CC BY-SA

London's taxi drivers have to pass an exam in which they are asked to name the shortest route between any two places within six miles of Charing Cross – an area with more than 60,000 roads. We know from brain scans that learning "the knowledge" – as the drivers call it - increases the size of their hippocampi, the part of the brain crucial to spatial memory.

Now, new research suggests that bigger hippocampi may not be the only neurological benefit of driving a black cab. While the average person likely has many separate mental maps for different areas of London, the hours cabbies spend navigating may result in the joining of these maps into a single, global map.

The grid-cell revolution

Decades of work in both humans and animals has led to great leaps in our understanding of how the hippocampus and nearby brain regions form maps of space. A key breakthrough was made by John O'Keefe in the 1970s, who used electrodes to record the activity of individual brain cells in the hippocampus of rats as they walked around. He found cells that were active at single locations in space and named them place cells. For example, one cell was active when the rat was at the top left corner of the room, while others were active when the was rat in the middle of the room.

Four decades later, the same technique was used to identify so-called grid cells. Like place cells, grid cells are active at specific points in space, but unlike place cells become active at multiple points organised in a repeating triangular pattern. Together, these cells and others are thought to be the cellular basis of the brain's spatial map, and their discovery led to the award of a Nobel Prize in 2014.

The repetitive pattern of grid cells means that they are activated in regular intervals as an animal explores an environment. It is thought that this repetitive activity can act like a ruler: by counting the number of times groups of grid cells become active, the rat's brain can calculate how far it has moved. Conversely, these cells could also be used to navigate between points in space by calculating how far you have to move to reach a goal. If grid cells did act as a ruler, to get consistent measurements, the distance between the points where the cells are active would need to be the same no matter where you are.

Yet this requirement has been questioned by recent findings showing that in certain places grid cell activity is distorted from its regular pattern. For example, the pattern is misshapen near to the walls of some environments, being particularly strongly affected in the corners of triangular spaces. It is therefore difficult to use the grid cells as a ruler in these places.

In the dark

To investigate this issue, we recorded grid cells in rats exploring two compartments connected by a corridor. Crucially, the two compartments were identical: they looked, smelled and felt the same. We hypothesised that if grid cells do act as a useful measure of space their activity should span the two compartments even though they are perceptually identical, reflecting the fact that each has a different position in space.

A number of unglamorous months were spent in a dark room scattering rice around the compartments to encourage the rats to explore, followed by the only slightly more glamorous analysis of the data. Happily, we observed a number of interesting results. When the rats first started to explore, the activity patterns of the grid cells were identical in the two compartments, reflecting the identical sensory cues in each.

However, once the rats had spent a number of days exploring, the grid cells' activity became more regular, eventually forming a single continuous pattern spanning both compartments. The grid cells had moved from having two separate and identical maps for each compartment to a single and continuous map covering both. Placing both compartments on the same map means that the grid cells can be used as a measure of space and for navigation between them.

While an interesting development, this will certainly not be the final word on the function of grid cells. Other studies have found apparently permanent distortions in their activity patterns, and it remains to be seen whether there are certain factors that prevent the regular pattern forming, and what they may be. Crucial future steps will likely include identifying how distortions in grid cell activity patterns relate to inaccuracies in navigation, and whether inactivating grid cells prevents accurate navigation.

Most studies use rodents to investigate the brain's representation of space, as recording from single cells in humans currently requires invasive surgery. Brain scans have shown that humans also have grid cells, but new technologies are needed before we can ask whether the grid cells of cab drivers form the same global patterns seen in our rats.

Source: The Conversation