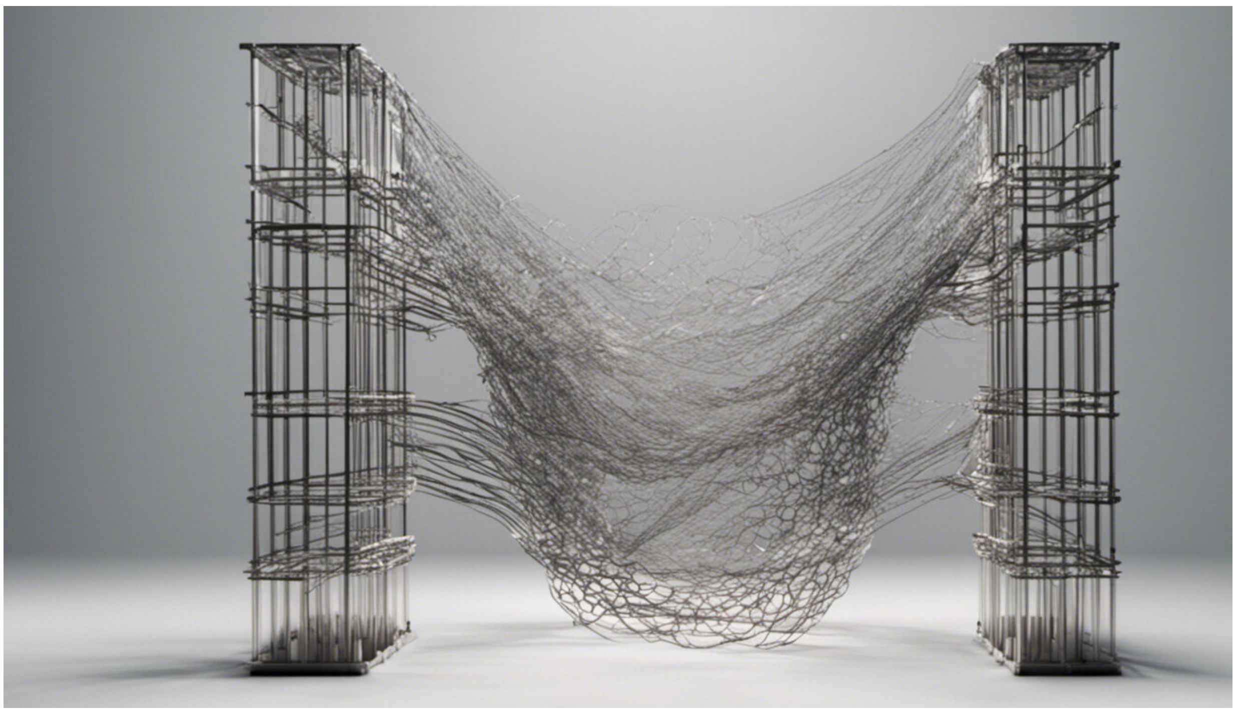
When a smell evokes a memory: Clues about how the two are linked in the brain

January 12 2022, by Michael Schmuker



Credit: AI-generated image (disclaimer)

In an episode of the popular TV series "Black Mirror" called "Crocodile," an investigator asks a witness to smell a bottle of beer. The aim is to refresh her memory of a crime scene (the crime took place near a brewery).

This might not exactly be standard practice, but our sense of smell, or olfaction, is known for its ability to elicit memories. We all know the feeling. A whiff of a particular scent can take you back to your grandmother's kitchen, the night of your first dance, or the sea shore.

And think of "scent marketing," where brand designers infuse "signature scents," for example in fashion stores and hotel lobbies, to enhance brand recognition across the globe.

Neuroscientists studying olfaction have long wondered about the connection between our sense of smell and memory. Is this relationship between memory and olfaction a result of the way the brain is wired? A study recently published in the journal *Nature* has broken important ground towards answering this longstanding question.

Before we look at the study, some background about how the brain facilitates our sense of smell. Scent molecules are initially detected by receptor neurons in the nose. The neurons send information about these encounters first to the olfactory bulb, a brain structure about the size of your fingertip located above the nasal cavity.

The olfactory bulb then sends signals to another brain structure called the piriform cortex. It is believed odor recognition happens there—that is, we identify its potential source, like an apple, a banana, or freshly cut grass.

What the researchers did

To study how the brain combines olfactory and spatial information, Cindy Poo and her colleagues at the Champalimaud Centre for the Unknown in Portugal had six rats complete a navigation task.

The rats had to repeatedly navigate a cross-shaped map with four corridors, as shown in the video below from about the two-and-a-half minute mark. At the beginning of each trial a light would point the rat down one of the corridors, where it would be exposed at random to one of four distinct smells (citrus, grass, banana or vinegar). The location of a water reward was dependent on which odor the rat was exposed to.

For example, the citrus odor meant the water reward was at the end of the south corridor. If the rat was exposed to the citrus smell in the east corridor, it would need to travel south for the reward. If it received the smell in the south corridor in the first instance, it could stay put and receive the reward. The idea was that with practice, a given smell would signal to the rat the location of the reward.

The surroundings of the maze were decorated with visual landmarks so the rats could also orientate themselves based on those landmarks. However, the rats' starting point was different in each trial. If it had been fixed, they could theoretically just have memorized a sequence of turns to find the correct corridor, and not used any spatial memory at all. This meant that completing the task successfully relied on a combination of spatial navigation and olfaction.

After about three weeks of training the rats did quite well; they were able to locate the water reward in roughly 70% of trials. This indicates that the rats were able to combine their internal map of the environment with locations of smells to locate the reward.

Looking at neuron activity

Neurons in the hippocampus, a part of the brain involved in memory and navigation, are known for functioning as "place cells." These are cells which become active at a specific location in an environment, which allows us to find our way around. Similar cells are also found in another part of the brain called the entorhinal cortex.

The most striking finding of the new study is that such location-selective cells are not only present in the hippocampus and entorhinal cortex, but also in a brain area linked primarily to olfactory function, namely the piriform cortex, the place thought to be primarily responsible for odor recognition.

The researchers in the study monitored the electrical activity of neurons in this area. Surprisingly, they found that only around 30% of neurons in this region of the rats' brains responded to specific odors. Another 30% of neurons fired in response to both a particular smell and location.

The remaining 40% of active neurons did not respond to specific odors at all, but rather to the locations where the rats had previously smelt the odors. These location-selective neurons would even start to fire when the rats were only just entering the corridor, before encountering any smell.

The researchers then wanted to understand whether the hippocampus and piriform cortex "talked" to each other while the rats were solving the puzzle. They found that cells in both regions tended to fire in synchrony while the rats were navigating the maze.

So what does this tell us?

These results show that the olfactory system may play a role in spatial navigation, and that spatial memory and olfactory information converge in the piriform cortex. But why has the brain evolved to represent location and odor in the same area?

The answer could be that odors are very useful clues for finding our way around. For example, a pine forest smells different from a meadow, while a fox's burrow has a different smell to a rat's nest. The rule holds even in man-made environments: an underground rail system smells different from a supermarket, an office different from a restaurant.

So our brains might be wired to associate smells with places because this has been useful in our evolutionary past.

This study was conducted in rats, which rely more on their sense of smell for navigation than humans do, since our perception is dominated by vision. But these findings do give new insights about how olfaction and spatial memory are likely connected in the human brain.