Virtual treasure hunt shows brain maps time sequence of memories

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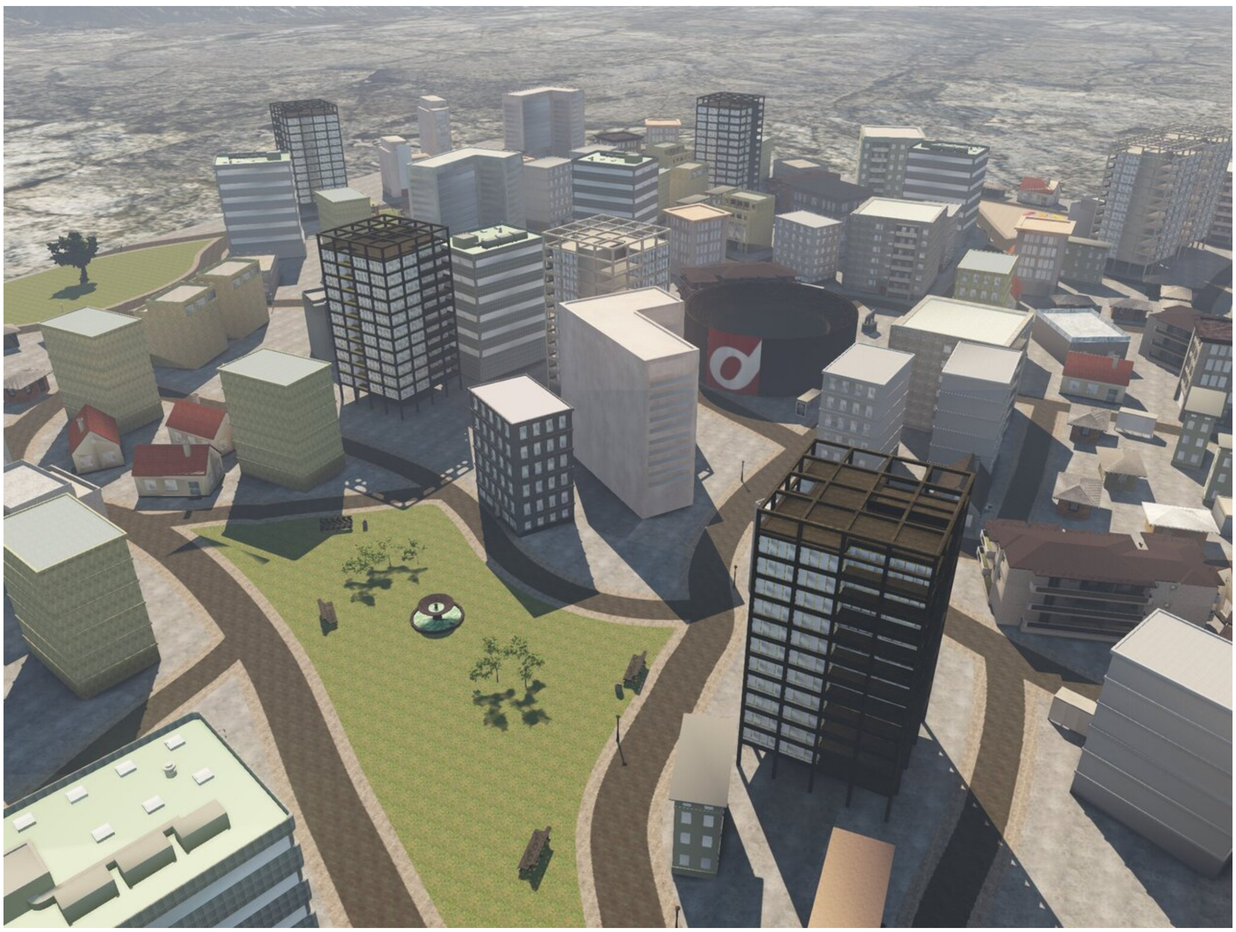

Participants learned a sequence of events by navigating a route through a virtual city. Credit: © MPI CBS/Bellmund

People have little difficulty remembering the chronology of events, determining how much time passed between two events, and which one occurred first. Apparently, memories of events in the brain are linked when they occur closely together. Using an experiment that combines virtual reality and brain scan technology, Jacob Bellmund and Christian Doeller from the Max Planck Institute for Human Cognitive and Brain Sciences describe how a temporal map of memories is created in the brain.

The entorhinal cortex, part of the medial temporal lobe, seems to play an important role. But how, exactly, does this part of the brain, near the amygdala and hippocampus, contribute to building a memory?

To learn more, the scientists had 26 subjects learn a sequence of events by navigating a route through a virtual city. They had to remember when certain objects appeared along the route and where they were in the city. Participants encountered chests along the route, which they were instructed to open. Each chest contained a different object that was displayed on a black screen when the chest was opened.

After learning, the researchers used an MRI scanner to measure how these events were displayed in the brain by showing the participants images of the objects in random order. "Events that occurred in temporal proximity are represented by similar activation patterns in the entorhinal cortex," explained Jacob Bellmund. "This means that when objects were shown that were temporally close along the route, this part of the brain reacted in a similar way. They were therefore more similar to each other than the activation patterns of events that occured at long intervals." Thus, the activation patterns of the entorhinal cortex reflected a kind of map of the temporal relationships of events.

The spatial relationships of the events, that is, the distance between the objects as the crow flies, could not be observed by the scientists.

The researchers used a trick to study space and time independently: Three teleporters on the route immediately 'beamed' the participants to another part of the city, where participants continued navigating the route. "This manipulation enabled us to vary the temporal and spatial distances between pairs of objects so that the spatial distance could be large, but the temporal distance very small," explained Bellmund.

The participants' recall of events in a later memory test was influenced by how distinct the temporal map of events in the entorhinal cortex was. They were asked to remember all the objects encountered along the route in the order in which they came to mind. Participants with an exact temporal map in the entorhinal cortex recalled events one after the other that occurred in temporal proximity. They listed the objects in order, as if they were mentally walking the route again.

Taken together, these findings show that the entorhinal cortex maps the time sequence of events and that this temporal map influences how people retrieve memories. These findings suggest that the brain stores our memories of experiences in a temporally organized way.

More information: Jacob LS Bellmund et al, Mapping sequence structure in the human lateral entorhinal cortex, *eLife* (2019). DOI: 10.7554/eLife.45333

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