The role of the hippocampus in how humans mentally travel in time and space

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Human and animal brains can represent events in time and space in fascinating ways, for instance, by accessing a chronology of events that happened in the past via stimuli perceived by the senses. In the human brain, spatial and temporal dimensions of events are combined and manifest in what is known as episodic memory, which can be elicited at any point while a person is navigating the world.

Episodic memory refers to the human ability to recall and play out specific experiences or events from the past. Past neuroscience studies suggest that the mapping of time-space associated with episodic memory is rooted in a specific region of the brain: the hippocampus.

Based on research findings gathered so far, humans are the only species on Earth also able to imagine chronological sequences that never happened but that might be in some ways connected to real events. This ability lies at the basis of what is known as causal reasoning, which entails identifying cause-and-effect relationships, such as 'if this thing happens in the future, then that other thing could happen."

Researchers at École Polytechnique Fédérale de Lausanne, Manipal Institute of Technology and Université Paris-Saclay have recently carried out a study investigating the role of brain regions within the hippocampus formation in the human ability to navigate through imagined events rooted in a different time or space. Their paper, published in theMIT Press *Journal of Cognitive Neuroscience*, offers valuable new insight about the neural underpinnings of what is known as ordinal psychological time in the human brain.

"Herein, we asked whether the hippocampal formation is involved in mental navigation in time (and space), which requires internal manipulations of events in time and space from an egocentric perspective," the researchers wrote in their paper. "To address this question, we reanalyzed a magnetoencephalography data set collected while participants self-projected in time or in space and ordered historical events as occurring before/after or west/east of the mental self."

Baptiste Gauthier, Pooja Prabhu, Karunakar A. Kotegar and Virginie van Wassenhove, the team of researchers behind the study, carried out an in-depth analysis of a dataset that they collected in one of their previous works. In their past study, they used time-resolved neuroimaging techniques to characterize the brain activity of a group of people that was asked to imagine historical events chronologically from different mental perspectives over time (e.g., nine years into the future) or in different spaces (e.g., while in a specific place).

In their new paper, the researchers review the data they previously collected using a different method. As the method they used in their past study had significant limitations that prevented them from investigating the implication of the hippocampus, they replaced it with a technique that explicitly accounts for the volume of the hippocampus.

The new source reconstruction method they used allowed them to clarify how deep structures within the hippocampal formation are involved in the human ability to mentally order imagined events in time and space from an egocentric perspective. The hippocampal formation is composed of several brain structures, including the bilateral hippocampi, entorhinal cortices and parahippocampal cortex.

"We found selective involvement of the medial temporal lobes (MTLs) with a notable lateralization of the main effects: Whereas temporal ordinality engaged mostly the left MTL, spatial ordinality engaged mostly the right MTL," the researchers wrote.

The results of the analyses shed some light on the contribution of brain regions within the hippocampal formation in ordinal psychological time, particularly that of the MTLs and MTL. While the exact function these regions is still unclear, their work suggests that they play a key role in mentally ordering hypothetical or imagined events occurring in different places and at different times.

In their paper, Gauthier, Prabhu, Kotegar and Wassenhove also introduce an hypothesis regarding how mental time and space travel might be processed by the hippocampal formation. More specifically, they suggest that the human ability to imagine traveling to different places or times could be guided by top-down control of neural activity within this particular brain formation.

Interestingly, the selective patterns of neural activity reported by the researchers occur when humans are mentally ordering events that they never experienced in real life (i.e., non-episodic events), but not when they mentally revisit actual events from their past. In the future, their findings could pave the way for new studies investigating ordinal psychological time in the human brain and focusing on the hippocampal formation, perhaps using new methods or newly compiled datasets.

More information: Baptiste Gauthier et al. Hippocampal Contribution to Ordinal Psychological Time in the Human Brain, *Journal of Cognitive Neuroscience* (2020). DOI: 10.1162/jocn_a_01586

Baptiste Gauthier et al. Building the Arrow of Time… Over Time: A Sequence of Brain Activity Mapping Imagined Events in Time and Space, *Cerebral Cortex* (2018). DOI: 10.1093/cercor/bhy320