Journal club

Spatial cognition

Leveraging virtual reality to understand human spatial navigation

The use of virtual reality (VR) environments for studying human cognition has opened new avenues of research, particularly in the field of spatial cognition. These simulated environments enable researchers to investigate place coding in the brain, specifically place cells and grid cells. The discovery of place coding cells is so scientifically relevant that the researchers behind it were awarded the 2014 Nobel Prize. These cells have been studied extensively in rodents that are allowed to move freely and in other animals. However, when we investigate neural mechanisms of spatial navigation in humans, the task becomes complicated for practical and ethical reasons.

Traditional methods of studying spatial cognition in humans used 2D low-level stimuli, such as a dot at a specific location on a computer screen. These studies also instructed participants to be at rest while performing the task, to accommodate the limitations and precautions associated with the measurement of cellular signals. Although non-invasive methods such as scalp electroencephalogram exist, they are limited to more superficial areas of the brain and do not afford cellular resolution.

The recording of place cell-like activity in humans (akin to rodents' place cells in the hippocampus) requires deep brain recording. This recording involves invasive procedures, typically the implantation of intracranial electrodes. Such procedures are usually performed on patients who need surgical treatments, and not on healthy individuals solely for research. As a result, these patients are typically instructed to remain at rest during navigation tasks, to reduce movement and lessen unnecessary risks.

The introduction of VR has mitigated some of these limitations, allowing researchers to study neuronal activity as participants navigate and interact with 3D virtual environments. This is an advantage over traditional methods because 3D environments provide a well-monitored and naturalistic setting. In both the 2D condition (where participants are instructed to locate a dot on a computer screen) and 3D conditions (where participants navigate through a virtual town in search of a landmark), spatial representations come into play. However, the latter scenario, facilitated by VR, provides continuous visual signals (known as optic flow). Continuous visual signals are relevant because they provide continuous feedback on self-motion, improving the precision of location tracking and orientation in space. Thus, VR methods broaden the type and extent of activities participants can safely do and allow measurement of neural activities during both simulated movement (for example, using keyboards or controllers) and free movement (for example, walking around in a designated area) in VR, which is closer to the situation in rodent studies.

This innovative approach has contributed to the scientific understanding of how human neurons respond to dynamic spatial information, as exemplified by studies such as the one conducted by Ekstrom and colleagues in 2003. These researchers cleverly combined VR with intracranial microwire recording to study the activation of neurons in the medial frontal and temporal lobes of patients with epilepsy in relation to dynamic spatial information. Their research revealed that cells in the hippocampus responded when participants were at specific locations in the virtual town, whereas cells in the parahippocampal region respond to views of landmarks, such as shop fronts. These findings provided evidence for place coding of spatial information during navigation, and underscored the potential of VR to reveal new facets of human spatial cognition.

I found the paper by Ekstrom and colleagues inspiring as a graduate student interested in understanding human cognition in naturalistic environments. The shift from 2D stimuli to immersive VR experiences makes it possible to study complex human behaviours and cognitive processes in a more realistic setting. It also resonates with my line of research on the use of naturalistic stimuli in cognitive studies. I see the value of using naturalistic stimuli in my studies because they contain rich and dynamic information, similar to the stimuli humans receive in the real world. Inspired by this naturalistic approach, my current project uses head-mounted VR and wire- less electroencephalogram recordings to recreate real-world navigation scenarios. My goal is to understand how humans integrate multisensory cues from self- motion signals during real-world spatial navigation, particularly when it involves walking.

The use of VR has expanded the horizons of cognitive research, as it offers a more naturalistic environment than 2D stimuli in which to investigate complex human behaviours and cognitive processes. As we continue to navigate through this dynamic research landscape, I am confident that VR will play a key role in uncovering the complexity of human spatial cognition, eventually contributing to a more comprehensive understanding of the interactions between humans and the world around them.

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Competing interests
The author declares no competing interests.

Original article: Ekstrom, A. et al. Cellular networks underlying human spatial navigation. *Nature* **425**, 184–188 (2003)

Related article: Stangl, M. et al. Mobile cognition: imaging the human brain in the 'real world'. *Nat. Rev. Neurosci.* **24**, 347–362 (2023)

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