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Press release

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Our brain's ability to organize action plans

How are the relations between different action plans organized and structured in the brain to support our rich behavioural repertoire? Irina Barnaveli, Christian Doeller together with Simone Viganò & Daniel Reznik from MPI CBS and with Patrick Haggard from University College London, argue in their recent study that the brain organizes action-outcome associations in a cognitive map-like structure. The researchers further demonstrate in their study, published in Nature Communications, that these cognitive maps, located in the hippocampal system, communicate with the motor system during action evaluation, suggesting that goal-directed action planning skills rely on multiple neural systems.

The human capacity to develop a diverse and highly complex repertoire of action plans is truly remarkable. Many of our behaviours are rooted in associations between actions and their outcomes, which we form and leverage flexibly. For instance, the same keypress action can lead to different outcomes depending on whether it's performed on a computer keyboard, a radio, or another context. We often have multiple alternative choices, so that action selection requires comparing across available action-outcomes, which is a non-trivial and taxing problem.

"How do we compare the many action plans stored in memory and select the most appropriate one? We propose that these action-outcome associations could be organized in a cognitive map within the hippocampal system, potentially supporting efficient action selection within the rich human behavioural repertoire" explains Irina Barnaveli, first author of the study. "The hippocampus is a part of the brain involved in forming memories and navigating in space. Navigation relies heavily on the creation of maps of space. Our study suggests that we create similar maps for organizing and selecting action plans, linking perception to action."

In the immersive virtual reality, participants performed a motor interaction task, in which they learned how to control the flying and catching of a virtual ball using different actions. Later, they compared learned actions while their brain activity was monitored using functional magnetic resonance imaging (fMRI). The scientists found patterns of brain activity that are typically interpreted as signatures of 'cognitive mapping', suggesting that the brain abstracts and organizes action plans in a map-like representation. This map is also evident from participants' behaviour: the closer the actions are within the hypothesised map, the more similar they are perceived by the participants. Crucially, this cognitive map in the hippocampal system exchanges information with the motor system to relate multiple action plans to each other.

"The map-like representations might therefore represent how humans interact with their environment in a very general sense, well beyond the specific case of spatial navigation. By supporting action selection, cognitive maps could contribute to optimizing the acquisition and exploitation of a wide repertoire of action plans. This discovery further challenges the classical distinction between declarative and procedural memory, suggesting that goal-directed actions rely on multiple neural systems that integrate action generation, motor planning, and memory", concludes Christian Doeller, last author of the study.

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In the VR Lab, researchers tested how our brain organises action plans.
MPI CBS