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A spatial path to mental time travel in humans

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Humans have a time machine in their minds. Episodic memory allows us to mentally re-experience past events, and episodic forethought to project ourselves into future events. Both of these capacities appear to be mediated by the hippocampus: an evolutionarily ancient part of our neural circuitry for spatial navigation. Since hippocampally mediated navigation is largely conserved across species, is the capacity for mental time travel also shared between humans and other animals?

In his dialog with Suddendorf [1], Corballis [2] points to hippocampal place-cell findings in rats – that a rat remembers a walked-through path or imagines a possible path that it could walk through in the future – as evidence that many members of the animal species should be capable of mental time travel. Thus, he endorses Darwin's statement that the human and animal mind differ in degree and not in kind. Yet, although many species rely on the hippocampus to navigate spatial paths, it is possible that only humans exploit this ancient capacity in a way that supports episodic thinking about the past and future [3–5].

Across languages, people express time in terms of space. In English, the future is *ahead* and the past*behind* [6], suggesting that speakers travel metaphorically along a sagittally oriented path through time. In other languages, the path may be vertically oriented [7], East-West oriented [8], or may follow a more complex trajectory [9]. Nevertheless, talking about time metaphorically (and according to experimental evidence, *thinking* about time metaphorically) in terms of space appears to be a human universal.

Conceptualizing time as a spatial path may be critical for the human capacity for mental time travel [3–5]. As humans and other animals experience time, it flows unidirectionally: we can never move pastward in time, we can only move futureward. Yet, movement along a spatial path can be bidirectional: we can travel forward or backward in space. Perhaps it is via our metaphorical construction of time that we arrive at the notion of flexible mental time travel. Once time is conceptualized as a spatial path it, too, can be traveled bidirectionally, forward or backward – at least in our imagination.

Do other animals conceptualize time spatially the same way that humans do? One study directly compared representations of space and time between humans and Rhesus macaques [4]. Subjects saw lines appear on a screen and judged whether they were longer or shorter than a memorized standard, in space (distance) or in time (duration). The humans' time judgments were strongly affected by irrelevant spatial information, demonstrating the predicted dependence of temporal thinking on space. The macaques showed a different pattern, which did not suggest any special dependence of time on space in their minds. To date, there is no evidence that nonhumans conceptualize time metaphorically in terms of space, as humans do. Spatialized time may be fundamental to mental time travel, and nonhumans may lack this foundation.

There may be other important differences between the spatial paths that humans travel in their minds in and the spatial paths encoded by the rat's place cells. The rat can remember or anticipate objects or other landmarks that occur along a spatial path. For humans, however, what lies ahead or behind on a mental path through time could be an abstract event with no sensory correlates like "your retirement." Humans can not only locate such abstract entities in time, we can also manipulate their locations. In our experience,

events occur in one specific order, but in our imagination we can reorder events in time like we can rearrange objects in space.

The difference between mental time travel in humans and animals may yet be one of kind, and not just one of degree. The “flexible foresight that is so characteristic of humans” [1] in mental time travel may depend on the capacity to spatialize time – a capacity that appears to be universal in the human species, but which has yet to be shown in any other species.

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