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Mental time travel: continuities and discontinuities

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Over 15 years ago, Michael Corballis and I first discussed the evolution of the human capacity to travel mentally in time [1]. Extensive research has since aimed to demonstrate similar nonhuman animal capacities [2], but Corballis and I have repeatedly found the evidence wanting [3,4]. It is hence noteworthy that, in light of new neuroscientific data [5,6], Corballis is now questioning whether mental time travel is uniquely human [7]. Here, I outline reasons why I think the evidence fails to show that animals travel mentally in time as humans do.

Corballis suggests that 'the main ingredient missing' from animal studies is evidence of what Tulving called 'autonoetic consciousness', and that recent studies on rat brain activity associated with spatial learning in mazes may be neural correlates of such consciousness. Hippocampal place cell sequences are sometimes reactivated during passive awake states in ways that suggest the rat considers trajectories [5,6]. Alas, as Corballis admits, we do not know what the animal subjectively experiences and whether a particular type of self-knowing consciousness is involved.

Because of the problems of assessing consciousness, Corballis and I have long been at pains to establish behavioural indicators of mental time travel [3,4]. Evolution cannot select for a private experience unless there are some tangible benefits for fitness, and humans clearly gain such benefits through flexible planning and prudent preparation. This is empirically tractable. Corballis and I distilled four behavioural criteria for experimental approaches that rule out common alternative explanations for future-directed actions [4]: (i) use of single trials to avoid repeated exposure to the same stimulus–response relations; (ii) use of novel problems to avoid relevant learning histories; (iii) use of different temporal and spatial contexts for the critical future-directed action to avoid cuing; and (iv) use of problems from different domains to avoid specific behavioural predispositions. A first study using all these criteria found that, by age 4, children can behaviourally demonstrate mental time travel [8]. The main ingredients missing from current comparative data, I believe, are not signs of autonoetic consciousness, but replicable behavioural evidence of this kind.

Corballis writes that the hippocampal activity of rats is likely homologous to that involved in human mental time travel. Note, however, that many involved neural processes (e.g., those associated with working memory) are likely to have homologous counterparts in other animals. Yet, this need not entail that animals travel mentally in time as humans do. Rats may, for instance, lack certain components critical to the human capacity. Corballis and I called this 'the multiple limits hypothesis' [3]. We have proposed several sophisticated components implicated in successful episodic foresight, since humans mentally populate spatial scenes with actors and actions, embed scenarios into larger narratives, and reflect on the likelihood or desirability of different options. Species (and individuals) may fail to display foresight because of shortcomings in any one of these. For instance, one important capacity is recursive thought, which allows us to flexibly combine and recombine basic elements to simulate almost any future situation. There is no evidence to suggest rats have recursive capacities, and there is evidence that they fall short on other components [2]. Thus, even if it could be shown that rats draw on autonoetic consciousness in their navigation of mazes, their capacity may be radically restricted in diverse ways [3].

Therefore, I do not think it is useful to resurrect Darwin's blanket statement that differences in mind between humans and animals certainly are one of degree and not of kind. The picture is more complicated [9]. Even when we find evidence for apparent differences in degree, this need not rule out that differences in kind are also entailed: as temperature gradually increases, the properties of H_2O change in kind as it transforms from a solid, to a liquid, to a gas. By the same token, continuous increase in, say, working memory capacity, may well lead to discontinuous changes in what a mind can possibly conceive of [10]. I see no reason why mental time travel should not have evolved gradually through Darwinian descent with modification. However, continuity over evolutionary time (e.g., from *Australopithecines* to *Homo*) should not be confused with a need to postulate an absence of gaps in the distribution of traits among extant species [9]. As transitional forms go extinct, vast qualitative differences can certainly emerge. On current evidence, it still appears that human mental time travel is profoundly special. There are few signs that animals act with the flexible foresight that is so characteristic of humans.

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The wandering rat: response to Suddendorf

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It was Thomas Suddendorf [1] who sparked my interest in mental time travel and, at his instigation, we set up what we thought were the necessary criteria to establish behavioral evidence for mental time travel in nonhuman species. These criteria are perhaps yet to be convincingly met in animal research. They are, however, essentially behavioral. Neurophysiology can provide a further avenue of investigation and arguably give a better perspective on what is 'mental' about mental time travel.

Hippocampal activity is clearly associated with mental time travel in humans, and parallels are increasingly evident from hippocampal recording in the rat. I have already noted evidence that activity in the rat hippocampus when the animal is outside of a maze signals previous paths within the maze, as well as paths not traversed, raising the possibility of anticipated future activity [2]. Further evidence of activity signaling future behavior comes from rats trained to alternate left and right turns at a particular location in a maze. Between trials, the rats were introduced to a running wheel and, while they were running, differential activity in the hippocampus signaled which turn they would take next. (My mind wanders, too, when I'm on a treadmill). Based on this and other findings, the authors concluded that self-organized activity in the hippocampus, 'having evolved for the computation of distances, can also support the episodic recall of events and the planning of action sequences and goals' ([3] p. 1327).

Mental time travel in the rat, if indeed it exists, is no doubt less complex than it is in humans. As Suddendorf suggests, the critical question is whether this amounts to a fundamental discontinuity. At one extreme, one might argue that the evidence based on hippocampal recording in the rat is already evidence for mental time travel. At the other extreme, one might consider the added complexity sufficient to make human mental time travel different in kind. To be sure, there is no evidence that the imagined wandering of the rat includes other individuals, things, and complex actions in addition to sequences of locations, as it does in humans. Neither is there evidence for the sheer number of real and imagined events that we humans carry or create. Nevertheless, it would not be surprising if mental time travel evolved from brain networks, present in rats as in humans, adapted for the representation of space and of sequences of locations within space, and even for keeping track of time [4]. Moreover, our common ancestry with the rat goes back some 75 million years, so evidence from the rat should, if anything, understate the case for interspecies continuity.

On the question of human uniqueness, it may also be pertinent to ask where the burden of proof lies. We have a strong tradition of respecting the principle of parsimony, whereby the simplest of possible explanations is to be preferred. Explanations are considered 'simple' to the extent to which they do not involve higher thought processes, such as language or, for that matter, mental time travel. The 'Clever Hans' debacle is often cited as an example of failure to apply this principle [5]. By contrast, applying overly simple explanations for animal behavior can lead to smug superiority and the invocation of miracles, such as the 'great leap forward' to explain why only humans are capable of language [6]. From a Darwinian perspective, it might sometimes be more prudent to assume differences in degree rather than in kind as the default position, and seek evidence that this is not the case.

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