No doing without time[†]

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ABSTRACT
Hoerl & McCormack claim that animals don't represent time. Because this makes a mystery of established findings in comparative psychology, there had better be some important payoff. The main one they mention is that it explains a clash of intuition about the reality of time's passage. But any theory that recognizes the representational requirements of agency can do likewise.

Humans live in a world imbued with time and temporal possibility, but Hoerl & McCormack (H&M) claim that animals don't. More precisely, although animals' representation of the world is sensitive to the passage of time, it contains no representation of time, and hence no representation of change, either. Such an account can perhaps explain how bees and other animals are able to return to a food source that becomes available at the same time each day. The animals can learn to associate the availability of food with the position of the sun in the sky. But how can animals lacking any representation of time learn an interval reward schedule, rather than one linked to time of day? Bumble bees can do this (Boisvert & Sherry 2006), as can hummingbirds, who can learn the varying rates with which different types of flower replenish their nectar, timing their visits accordingly (González-Gómez et al. 2011).

H&M allow that animals have various clock-like mechanisms that change regularly with the passage of time. But it remains mysterious how these mechanisms could issue in interval learning without time being represented and remembered. Suppose that a hummingbird visits a flower, finds it full of nectar, and drains it. It therefore forms a representation of the world as containing no nectar at that location. After 20 clicks of its internal clock, it happens to revisit the flower believing it to be empty, but finds it full,

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[†] This is the penultimate version of our commentary on Christoph Hoerl and Teresa McCormack's (2019) target article, "Thinking in and about time: A dual systems perspective on temporal cognition", published in *Behavioral and Brain Sciences*, vol. 42, e244: 1–69.

again draining it. Then, after 10 clicks of its internal clock, it happens to revisit the same flower again (why?), and finds it almost empty. If its internal clock gives rise to representations of time, the bird can now store the information that the flower takes between 10 and 20 clicks to replenish. But if it can't, how does the bird learn to visit the flower in the future when 20 clicks have elapsed, but not when only 10 have? Somehow, the ticking of its internal clock must cause its representation of the flower as empty to flip to representing it as full once significantly more than 15 clicks have elapsed (but after some other number of clicks for a different type of flower). We have no idea how H&M think this is supposed to happen, and would welcome clarification.

Moreover, there has been an immense amount of theorizing and successful data-collection within the broad framework of optimal foraging theory (Pyke 1984). It is generally assumed that an animal's decision to leave one patch for another depends on a comparison between the rate of reward at the current patch with the average rates previously experienced, together with an estimate of travel-time between patches. But a rate is a measure of quantity per unit of time. And indeed, it turns out that animals can be extraordinarily good at estimating rates, and adapting swiftly to changes in rates (Gallistel & Gibbon 2000; Gallistel et al. 2001). This literature assumes that animals can represent the passage of time, integrating representations of time with representations of quantity to issue in an estimated rate. It is mysterious to us how any of this could be done without representing time. How is the clicking of a body clock supposed to give rise to a representation of rate unless it can give rise to representations that can be integrated with representations of quantity? Here, too, we would welcome clarification.

Because H&M's claims seemingly require overturning established science, there had better be some important payoffs from accepting their view. One thing they discuss that is of particular interest to us is that their dual-systems view can explain the existence and persistence of certain contradictory elements in people's naïve theory of time. In their account, adults' temporal reasoning system, representing reality as temporally extended, implies that the present is but one temporal perspective among many (hence not ontologically privileged). Yet the temporal updating system, representing reality in a non-temporally qualified manner, produces what might be called a "present bias" that views the present as ontologically special. Importantly, because the temporal updating system is the more primitive of the two, it works automatically, delivering its verdict despite contradicting the more sophisticated temporal reasoning system. It therefore explains why even philosophers and physicists who are convinced that time does not really pass, still find time's passage intuitively irresistible.

However, a dual-systems approach isn't needed to explain the contradictory elements in people's naïve theory of time. As an alternative possibility, suppose that only the temporal reasoning system is at work. Its representation of reality has time as one of the dimensions, of which any subjectively indexed present moment is but one among many "locations." Such a representation, generated by temporally bound agents with temporally sensitive goals and desires, should recognize the distinction between past, present, and future in an agent-relative way. Indeed, H&M allow that the temporal reasoning system represents temporal order and tense. Once this much is permitted, the present bias can simply arise as an adaptation for successful action planning and execution *within the temporal reasoning system*, for the present marks the boundary between what cannot be changed (past) and what humans as intentional agents can still exert causal influence on (future). Plausibly, acting or planning to act *at the present time* is conducive to bringing about desired changes, which are themselves aimed for, *given the present state of the world*. It is therefore adaptive to include in one's temporally extended representation of reality the asymmetry of causal influence (Horwich 1987; Kutach 2011). The present then becomes privileged as a result of the requirements of agency.

In the alternative just sketched, it remains true, as H&M highlight, that people often cannot dislodge the impression that the present exists simpliciter, without temporal qualification. But our alternative does not posit a primitive system that fails to represent time per se. Rather, it is that it is adaptive to prioritize addressing present needs and challenges, even at the cost of representing past and future as "less real." In this sense, the persistent present bias might well be an "adaptive misbelief" à la McKay and Dennett (2009).

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