Therefore, contrary to the authors' suggestion, we argue that Sumatran orangutans possess the necessary representational resources for temporal reasoning. Looking back at Peacocke's criteria for temporal representation, it appears that orangutans must have a capacity to track other conspecifics across space and time, so as to coordinate their activities with the facilitation of nightly long calls. Other conspecifics appear to retain a conception of their environment that is updated with a "past-tense label" corresponding to the time since hearing the long call and "register the identity" of the emitter of the long call and the orangutan they aim to meet or avoid at a certain future time/place. This is not to say that it is impossible to posit a mechanism that does away with such temporal representations and accounts for such behavior by having the appropriate temporal dynamics. However, for the reasons mentioned above, this appears to us ad hoc and unmotivated.

On a final note, none of this is to deny that human beings have distinctive ways of representing and reasoning about time – grounded in their more intellectually demanding conceptual and linguistic skills. Rather, it is to deny H&M's claim that the latter, alone, amounts to *genuine* temporal representation, and their conception of creatures who are differently intellectually equipped as "cognitively stuck in time" (sect. 2.3, para. 3).

Updating and reasoning: Different processes, different models, different functions

Laura Kelly[a], Janani Prabhakar[b] and Sangeet Khemlani[a]

[a]Navy Center of Applied Research in Artificial Intelligence, U.S. Naval Research Laboratory Washington, DC 20375 and [b]Center for Mind and Brain, University of California Davis, Davis, CA 95616.
laura.kelly.ctr@nrl.navy.mil jprabhakar@ucdavis.edu
sunny.khemlani@nrl.navy.mil
www.laurajanekelly.com
www.jananiprabhakar.com
www.khemlani.net

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Abstract

Two issues should be addressed to refine and extend the distinction between temporal updating and reasoning advocated by Hoerl & McCormack. First, do the mental representations constructed during updating differ from those used for reasoning? Second, are updating and reasoning the only two processes relevant to temporal thinking? If not, is a dual-systems framework sensible? We address both issues below.

Hoerl & McCormack (H&M) distinguish between temporal updating and temporal reasoning as separate mental processes. The distinction is sensible and useful, and it helps synthesize many extant results in temporal cognition. Nevertheless, the authors' framework prompts two issues worth clarifying:

First, what is being updated during temporal updating?

The authors elaborate on specific constraints of the temporal updating process, but they are less clear on the mental representation that is being updated, which they refer to as a "world model." The world model they refer to bears resemblance to "perceptual mental models" described in research on event segmentation, visual perception, and mental simulation (Chua et al. 2005; Churchland et al. 1994). The distinction offered by H&M, that perceptual models and event models may be fundamentally distinct in both evolutionary and developmental terms, could help frame current theories of event cognition so long as the factors that distinguish the two are clearly delineated.

Our own recent work (Kelly 2018; Khemlani et al. 2013; 2015) can help distinguish perceptual models – which the temporal updating system produces – from event models, which are constructed during temporal reasoning. Some fundamental differences between perceptual models and event models are provided in Table 1.

The table shows that both perceptual and event models are iconic, discrete simulations that represent a possible set of relations between entities. But while perceptual models come from using perceptual information to update a model of a reasoner's surroundings, event models can represent situations apart from the reasoner's ongoing experience. They can come from discourse concerning real or hypothetical scenarios that are spatiotemporally displaced; episodic memory of events in the past; and imagination about events in the future. Unlike perceptual models, event models can concern multiple situations. Consider the following description of a set of events: "The commute happened before the staff meeting. The commute happened before the conference call." The description is consistent with at least two temporal possibilities: one in which the meeting happened before the call, and one in which the call happened before the meeting. Those who fail to enumerate the different possibilities will fail to grasp the ambiguity of the description (Kelly & Khemlani 2019). Event models permit reasoners to enumerate multiple possibilities.

The table lists additional ways in which we believe perceptual models differ from event models. The differences are anticipated in part by H&M, who argue that "the temporal updating system … deals with changing input by *changing representations*, rather than by *representing change*" (sect. 1.1, para. 1). If H&M are right that temporal updating is a highly constrained cognitive process, then the representations it updates should be constrained in systematic ways that yield testable empirical predictions.

Second, is a dual-systems framework appropriate?

When theorists invoke a dual-systems account of reasoning, one fundamental assumption is that the two systems compute the same function in two different ways: an initial, rapid system computes a heuristic response based on one or more cues, and a slower, deliberative system processes the same information in a more elaborate manner (Stanovich & West 2000). The two systems rely on different algorithms to carry out the same cognitive task. But when H&M distinguish updating from reasoning, the goals of the two systems they posit differ: People update their perceptual models to maintain an accurate simulation of reality. In contrast, a person may engage in temporal reasoning to achieve many different goals, for example, planning for the future, reinterpreting the past, comprehending discourse, and understanding the sequence of a film. Because temporal updating and temporal

Table 1. Conceptual and computational differences between the perceptual and event models

A perceptual model…	Event models…
is an iconic, discrete mental simulation of ongoing experience	…are iconic, discrete mental simulations of temporal possibilities
…comes from perception	…come from perception, discourse, memory, or imagination
…represents a single situation	…can represent multiple situations
…is subject to attentional and working memory bottlenecks	…are subject only to a working memory bottleneck
…can't be used to infer temporal relations	…can be used to infer temporal relations

reasoning are used for different purposes, invoking the dual-systems framework may be inappropriate.

Indeed, it is not clear to us why updating and reasoning are the only processes relevant to temporal cognition. Some tasks that require the representation of time do not require reasoning at all. Consider the task of event recall (Wang & Gennari 2019). The task requires an individual to recall events that comprise some temporal interval. For example, you might summarize your previous day as follows: "I had breakfast, worked on a project, taught a class, had a meeting, then had lunch with a friend…." The task requires individuals to remember and then to represent multiple events along a mental timeline. It does not concern temporal updating and it does not require reasoning, either, because responders need not infer any novel temporal relations while recalling events in memory. The act of remembering a temporal sequence seems fundamental to temporal thinking, but the dual-systems framework that H&M espouse has no place for it.

Hence, H&M must explain whether their account allows for cognitive processes that result in mental representations of temporally ordered events, even those that do not demand explicit temporal reasoning. The "intermediate developmental stage" (sect. 3, para. 1) to which they refer presents a broad challenge to the dual-systems framework. Children may struggle to retrieve temporal sequences, not because they revert to updating, but rather because of episodic memory retrieval failures (Prabhakar & Ghetti 2019). H&M should enumerate the specific pattern of errors predicted by reverting to the updating system. Perhaps a more accommodative framework, one that retains the division outlined by H&M, should specify the different processes relevant to temporal cognition (e.g., updating, recall, reasoning) as well as the various representational and computational constraints of each process (cf. Khemlani et al. 2015).

In sum, H&M's distinction between temporal updating and reasoning is useful, so much so that it is worth refining, clarifying, and extending to address the two issues highlighted above.

The "now moment" is believed privileged because "now" is when happening is experienced

Ben Kenward and Michael Pilling

Department of Psychology, Oxford Brookes University, Oxford, OX3 0BP, United Kingdom.
bkenward@brookes.ac.uk mpilling@brookes.ac.uk
www.brookes.ac.uk/templates/pages/staff.aspx?uid=p0078109
www.brookes.ac.uk/templates/pages/staff.aspx?uid=p0075139

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Abstract

Hoerl & McCormack risk misleading people about the cognitive underpinnings of the belief in a privileged "now moment" because they do not explicitly acknowledge that the sense of existing in the now moment is an intrinsically temporally dynamic one. The sense of happening that is exclusive to the now moment is a better candidate for the source of belief in a privileged now.

We agree with Hoerl & McCormack (H&M) that the naïve folk conception of time is paradoxical, particularly with respect to the sense of a privileged now. However, we argue that because H&M have placed little emphasis on the subjective experience of the "now moment," they are likely to be wrong about the cognitive underpinnings of the belief in a privileged now. We doubt that the belief in a privileged now arises from an ancient cognitive system that represents the world without representing change, because the conscious experience of the now moment is inherently the experience of change.

A better model for the way humans think about time should not explain belief about temporal change primarily only with respect to thoughts about the past and future. Instead, the model should incorporate the variety of mechanisms for processing temporally dynamic stimuli that each present different kinds of temporally dynamic experience to conscious awareness in the now moment (Montemayor & Wittmann 2014; Muller & Nobre 2014). Mental time travel (Suddendorf & Corballis 2007a), which H&M rely on completely to account for the naïve human idea of time, is only one way in which humans relate to the passage of time. Yet it is arguably the least direct way we experience time because it is normally experienced only as simulation.

A more direct way we experience time is through the *flow* inherent to the sense of the present moment, which is a dynamic sense of events *happening* in the now, widely acknowledged within discussions of the phenomenology of time (Gruber et al. 2018; Prosser 2012). At any given moment, there is not only (or not at all) a subjective representation of now as a snapshot with no sense of change. There is a sense of flow; now is a single moment, but it is a moment encompassing change. The dynamic nature of the conscious sense of now is revealed in widely used phrases such as "stream of consciousness" and "what is happening now." Readers unfamiliar with the phenomenological literature are invited to engage in introspection about their experience of existing in the current moment. Even in a stimulus-poor environment, our experiences in the now moment are dynamic, including breathing, or chains of thoughts. Perceptions in the now are frequently of momentary dynamic events: a flash of light, a spoken word, a looming object. Many conscious perceptions are meaningless outside the context of temporal dynamics. For example,