the sense of looming and other motion perceptions inherently relate to change (Gibson 2014), and sound is inherently a temporal phenomenon.

Besides the phenomenological or introspective analysis, various objective observations indicate that the now moment encompasses happening events rather than just a millisecond snapshot. For example, multiple events occurring within a time window (up to 300 ms depending on modality and number of events) can be discriminated even though their order cannot be determined (Montemayor & Wittmann 2014), indicating that they were experienced as separate happenings within one moment. Further evidence, for example, from language perception, indicates that there are different kinds of experience of now, with different aspects of dynamism (Poeppel 2003; Wittmann 2011). The "simultaneous now" is suggested to last approximately 250 ms (still long enough to contain events), whereas the "conscious now" lasts approximately 3 seconds (Montemayor & Wittmann 2014).

Further evidence for the sense of events happening now comes from work on visual perception. Suitably arranged dynamic stimuli together give rise to our sense of causality in the here and now (Scholl & Tremoulet 2000). In the same way that changes to the dynamic character of the stimuli can abolish the sense of causality, disruptions to the temporal sequence can also remove the sense of happening that is a cornerstone of the subjective sense of temporal flow (Gruber & Block 2013).

There are numerous functional reasons why the experience of the now moment must be more than a millisecond snapshot. Our perceptions are integrated with our actions (Pezzulo & Cisek 2016), with the consequence that our perception of the now moment is one of the dynamic affordances currently offered. To perform even the simplest goal-directed actions, short-term temporal dynamics are taken into account (Gibson 2014).

Interestingly, there is evidence that on the lowest levels of subconscious perception, stimulus representations are in fact not dynamic, and perception rather takes the form of a series of discrete static representations. This is even held to be plausible for auditory stimuli although sound is inherently temporally dynamic (VanRullen et al. 2014). The dynamic perceptions reaching our awareness are therefore not necessarily veridical in the sense of arising directly from the true dynamism of real events. Rather, this is likely to represent a reconstruction (Gruber et al. 2018). However, the only thing that matters for our current argument is that the lowest levels of perception subject to conscious awareness usually constitute dynamic representations.

We agree with H&M that there is little evidence for mental time travel in most non-human animal species or in human infants. However, given the different ways of experiencing time, it is arguably inappropriate to dichotomize organisms according to "whether or not [their] model of the world contains a temporal dimension" (sect. 1.3, para. 4). Rather than the lack of evidence of mental time travel implying that such organisms have no representation of temporal change, it implies they may have no representation of change except for the change happening in the current moment. In other words, their representational timeline may be very short.

Given the dynamism of the experience of now, our counterproposal for what makes now special in naïve human belief is that *now is the only time when events are experienced to happen.* Of course, events are also believed to have happened in the past and are expected to occur in the future, but mental time travel typically involves simulation rather than experience of those events. We argue that our account is more parsimonious than H&M's because their model implies a curious and unsupported phenomenon: that people ignore their salient experience that things happen in the now moment when they are thinking about what now actually is.

Let's call a memory a memory, but what kind?

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Abstract

Hoerl & McCormack argue that animals cannot represent past situations and subsume animals' memory-like representations within a model of the world. I suggest calling these memory-like representations as what they are without beating around the bush. I refer to them as event memories and explain how they are different from episodic memory and how they can guide action in animal cognition.

In the target article, Hoerl & McCormack (H&M) propose a dual-systems account for temporal cognition and argue that non-human animals can only use the temporal updating system whereas humans utilize the temporal reasoning system as well. I am sympathetic to dual-systems approaches in general, but it seems that H&M try to explain too much with too little in animal cognition.

In H&M's view, the model of the current world does all the heavy lifting in animal cognition. The model represents how things are in the current environment; contains information about objects, their features, and locations including goal states; supports single-trial and sequential learning; and can be updated as things change in the environment. Yet this notion of a model is left unpacked. If the model is just for the present state of the world, why not use the world as its own model? Is the model just a cognitive map or a full-blown replica of the world? What is the format in which the information is stored? Is it perceptual or propositional or something else? Is the model constructed componentially? If so, what binds different kinds of representations into a single unit? If not, how could the model be updated so swiftly? Without answers to these kinds of questions it is difficult to assess whether non-human animals operate with a model or not.

Arguably, any attempt to specify what a model of the current world consists of has to include perceptual elements that go beyond an animal's immediate sensory range. H&M seem to agree with this, as they accept that non-human animals can continue to represent an object that they no longer perceive as part of their current environment. These memory-like representations are obtained from the animals' past experiences and are presumably retained insofar as they are useful for the organism. H&M want to subsume these memory-like representations within an animal's model of the world, but it is possible to be more precise here.

In earlier work (Keven 2016; 2018), I called these types of representations event memories and argued that we can understand the mnemonic abilities of non-human animals (and young children) with event memory without ascribing them a capacity for full-blown episodic memory. According to the dual-systems thesis that I proposed, event memory is a snapshot-like memory system predominantly in the form of visual images, whereas episodic memory requires additional higher-order *inferential processes*. The episodic memory system takes event memories as inputs and binds them into a whole by linking multiple events into a temporal sequence, establishing casual relations between temporally separated events and arranging events in a converging structure such that multiple events are bound together to enable an outcome. Unlike episodic memory, temporal, causal, and teleological relationships between events are not specified in event memory. Event memories are fleeting and fragmentary in this sense as they are not bound into a stable whole. Hence, event memories are retained as long as they are relevant for current tasks, otherwise they are rapidly forgotten.

H&M claim that such free-floating representations cannot systematically guide action. Although event memories are not bound into a stable whole, they are still tied to the current goals of the organism and can be activated by task-based cues from working memory. In this respect, event memories differ from Redshaw's (2014) uncontextualized representations, as the goals of the organism actually relate event memories to the current context. This is a different kind of contextualizing than what Redshaw seems to have in mind, as it still does not require meta-representational abilities. Instead, the current goals of the organism activate relevant representations that are associated with achieving that goal (Hommel 2009; Hommel et al. 2001). The idea is that when an organism is engaged in a task, task-relevant representations, such as recent events, locations, and other relevant perceptual or semantic information, are activated. If the task is time sensitive, this process could also incorporate temporal information from an interval timer mechanism similar to what H&M envisions. These activated representations can then guide the selection of actions according to their expected outcomes.

To illustrate how this process might work, consider Clayton and Dickinson's (1998) original study that H&M discuss. Event memory can assist scrub jays by keeping track of caching events (i.e., what did the bird cache where). Because the recovery task is time sensitive, the birds could also use an interval timer mechanism to control how long these event memories would remain task relevant. During the training phase of the study, scrub jays seem to learn that worm-caching events are relevant for the recovery task only for a short time period and there is no need to retain them for longer. In 124-hour trials, then, the birds could actually be operating with only the event memory of caching peanuts, and hence they search for peanuts. In 4-hour trials, however, because the elapsed time is short, event memories for caching peanuts and caching worms would both still be active. In this case, the birds search for worms as their preferred food.

It is important to note that none of these processes require remembering the actual experience of caching the food items, unlike an interpretation based on mental time travel (Salwiczek et al. 2010). The birds could remember in the same way I can remember where my keys are without remembering the actual experience of where I put them (Malanowski 2016; Suddendorf & Busby 2003). Event memory is based on automatic perceptual processes and does not require conscious attention at encoding or retrieval.

To conclude, animals need to keep track of what has happened to effectively deal with day-to-day tasks that are extended over time. Event memory can guide animals by providing a record of progress in such tasks.

Thinking about time and number: An application of the dual-systems approach to numerical cognition

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Abstract

Based on the notion that time, space, and number are part of a generalized magnitude system, we assume that the dual-systems approach to temporal cognition also applies to numerical cognition. Referring to theoretical models of the development of numerical concepts, we propose that children's early skills in processing numbers can be described analogously to temporal updating and temporal reasoning.

Hoerl & McCormack (H&M) describe two systems that supposedly differ in the processing of temporal information and the underlying representation of time. We endorse this notion and propose that the dual-systems approach is not restricted to the dimension of time. The basic assumption is that time, as well as space and number, is part of a generalized magnitude system (Walsh 2003). Therefore, if we adopt the view of a generalized system for magnitude processing and, at the same time, accept the proposed dual-systems approach to account for the domain of temporal cognition, then the two systems should also apply to other domains of magnitude processing. In the following, we give examples of processes in numerical cognition that might correspond to those processes that H&M ascribe to the temporal updating system, an intermediate phase, and the temporal reasoning system.

The development of basic and advanced numerical knowledge in humans is assumed to rely on an evolutionarily ancient innate system dedicated to extracting and representing approximate numerical magnitude information (Amalric & Dehaene 2016; Feigenson et al. 2004; Piazza 2010; Starr et al. 2013). Recent meta-analyses support this view by showing a significant association between approximate numerical magnitude processing skills and symbolic math performance (Chen & Li 2014; Fazio et al. 2014; Schneider et al. 2017). We suggest that sensitivity for approximate number might be interpreted analogously to the elapsed-time