

whether all the criteria listed – recursion, causal understanding, and rehearsal, for example – are essential for mental time travel as opposed to being skills that humans have and use incidentally while engaged in MTT.

The type of criteria we have in mind can be illustrated by our own analysis of “episodic-like” memory. We used Tulving’s original definition of episodic memory in terms of spatio-temporal relations (Tulving 1972) to investigate whether western scrub jays have “what, where, when” (www) memory. We subsequently proposed additional behavioural criteria for “episodic-like” memory; namely, that the memory must not only be shown to have www content but also to have an integrated structure and that the information can be deployed flexibly (Clayton et al. 2003). Although our term “episodic-like” acknowledges the difficulty of interpreting behaviour in another species as a manifestation of a specific phenomenological experience of remembering, the important point here is that the what, where and when must be bound together in order that the animal can discriminate one event from another. For this reason even a ‘yes’ in every box in Table 1 of the target article is not sufficient to establish the episodic-like character of memory in the absence of the criteria of integration and flexibility.

Importantly, S&C do offer an empirically tractable criterion for foresight, the Bischof-Köhler hypothesis. This is the claim that an animal cannot take action for a future motivational state, and we have recently used this criterion to evaluate the MTT hypothesis by investigating whether scrub-jays who are not hungry cache more food in a place in which they are likely to experience hunger the following morning than in a place that they are not. Not only did they meet this criterion of MTT, but they also cached more of a type of food that they will not receive in a particular place the following morning than of a type of food that they will (Raby et al. 2007). In Shettleworth’s view this is the first unambiguous example of future planning in an animal (Shettleworth 2007).

What we do not know, and think is not testable empirically, is whether this type of future planning depends upon episodic personal projection or semantic knowledge. S&C are inclined to dismiss the semantic cognitive system as self-evidently inferior and more limited than the episodic cognitive system with a number of statements that there is no room to debate here. A contrasting view is that the only distinguishing difference between episodic and semantic memory is the phenomenological sensation of remembering rather than knowing about the event. The semantic memory system allows individuals to acquire information about themselves and their world through different sensory modalities and flexibly retrieve and use this information. This includes personal information and autobiographical facts. We agree with S&C that there is evidence that the episodic and semantic memory systems are closely linked to their respective future thinking counterparts and suggest that the only significant difference between episodic and semantic future thinking is the sensation of pre-experiencing one’s own personal future. Humans may always combine episodic and semantic future thinking in assessing alternatives, but this does not prove that the episodic element is essential for future thinking. Using one of their own examples, it is quite possible to semantically arrange a seating plan for a forthcoming event without needing mental time travel to envisage oneself at the table.

S&C argue that a demonstration of mental time travel in non-human animals must exclude behaviours that are species typical or domain specific, without adequately explaining why. They describe a possible test of episodic-like prospection in scrub-jays and then immediately dismiss it as explicable by “predispositions and specific learning algorithms,” although, in their view, the use of language by humans – surely a case of predisposition and learning if ever there was one – “provides the clearest evidence of [mental time travel].” Most behaviours in any animal, cognitive or otherwise, are likely to be species typical and a result of some form of predisposition and learning. They use a different yardstick

in assessing children than in assessing animals. Caching and retrieval may develop in a predictable fashion in scrub-jays, but so does the emergence of autoevidence, theory of mind, and indeed the episodic cognitive system in children.

In relying so heavily on phenomenology, S&C effectively define mental time travel by the exclusion of animals other than humans. If they are going to propose a comparative hypothesis it is incumbent on them to offer relevant, applicable, behavioural criteria which are empirically tractable. In the absence of such criteria, the comparative aspect of MTT is not a matter of scientific enquiry but of intellectual preference.

On the constructive episodic simulation of past and future events

DOI: 10.1017/S0140525X07002178

Daniel L. Schacter and Donna Rose Addis

Department of Psychology, Harvard University, Cambridge, MA 02138.

dls@wjh.harvard.edu <http://www.wjh.harvard.edu/~dsweb>

daddis@wjh.harvard.edu <http://www.wjh.harvard.edu/~daddis>

Abstract: We consider the relation between past and future events from the perspective of the constructive episodic simulation hypothesis, which holds that episodic simulation of future events requires a memory system that allows the flexible recombination of details from past events into novel scenarios. We discuss recent neuroimaging and behavioral evidence that support this hypothesis in relation to the theater production metaphor.

Suddendorf & Corballis (S&C) could hardly have asked for a better moment to focus on mental time travel. In recent months there has been a virtual explosion of relevant papers, including neuroimaging studies (Addis et al. 2007; Szpunar et al. 2007), investigations of amnesic patients (Hassabis et al. 2007) and scrub jays (Raby et al. 2007), a concept essay (Schacter & Addis 2007b), and two theoretical reviews (Buckner & Carroll 2007; Schacter & Addis 2007a). The future of thinking about the future appears to be now.

We focus on issues raised by S&C that are addressed by our recent work on past and future events. In particular, we consider two key ideas contained in S&C’s theater production metaphor: (1) memory is not a literal recording of experience; and (2) episodic future thinking – like episodic remembering – needs to be decomposed into constituent components.

S&C emphasize, rightly, that memory is constructive rather than reproductive. Though not a new idea, its links to future-related thinking have been overlooked (for exceptions, see Dudai & Carruthers 2005b; Suddendorf & Corballis 1997). To strengthen the link, we have advanced a *constructive episodic simulation hypothesis* (Schacter & Addis 2007a; 2007b). According to this hypothesis, remembering past events and imagining or simulating future events draw on similar kinds of information in episodic memory and involve many shared processes. In particular, episodic remembering and future thinking both depend critically on relational processes that link or bind together distinct elements of an experience. This latter idea is especially important because our hypothesis holds that episodic simulation of future events requires a system that allows the flexible recombination of details from past events into novel scenarios. Episodic memory possesses exactly these characteristics, which makes the system highly adaptive for simulating novel future scenarios based on past experiences, but also makes the system, when used for remembering, prone to errors and distortions that arise from miscombining stored elements – a common form of memory distortion.

This hypothesis predicts considerable overlap in the processes that support remembering the past and imagining the future.

S&C review such evidence, which is bolstered further by the recent studies noted earlier. For example, two new neuroimaging studies (Addis et al. 2007; Szpunar et al. 2007) build on earlier work from Okuda et al. (2003) by demonstrating that a number of prefrontal, medial temporal, and parietal regions previously associated with episodic remembering show similar increases in activity, relative to control tasks, when imagining the future or recollecting the past. A key finding with important implications for the constructive episodic simulation hypothesis is that the hippocampus shows increased activity when people construct and elaborate on both future and past events; indeed, the right hippocampus shows greater activity during construction of future than past events (Addis et al. 2007). Given the role of the hippocampus in supporting relational processing and perhaps other aspects of episodic memory, these data suggest that episodic simulation of future events involves an even more intense constructive process than does episodic remembering of past events.

Such observations mesh nicely with the recent findings from Hassabis et al. (2007) that four of five hippocampal amnesics exhibited deficits in the ability to imagine novel events. The fMRI findings also fit with a recent behavioral study in which we demonstrated that older adults, compared with younger adults, show reduced specificity both in their recall of past autobiographical episodes and their imaginings of possible future episodes (Addis et al., in press).

S&C's theater production metaphor highlights the need to decompose the complex activities of mental time travel into more basic components. Such componential approaches have been usefully applied to memory by numerous investigators, and should be similarly helpful when applied to future event simulation. Consider, for example, the finding from our fMRI study that several brain regions show greater activity during future versus past event construction (Addis et al. 2007). As noted earlier, one of those regions is the right hippocampus. Another such region is a medial part of right anterior prefrontal cortex (BA 10). If we think of these regions as components a network used for past and future event simulation, the next task is to characterize their respective contributions. In the context of S&C's theater metaphor, we suggest that medial BA 10, assisted by hippocampus, might serve as the "stage" on which the production unfolds.

S&C discuss the stage component with respect to Baddeley's well-known tripartite model of working memory, consisting of a central executive, phonological loop, and visuo-spatial sketchpad. Note, however, that Baddeley (2000) updated the model to include a fourth component, the episodic buffer. In the updated model, the central executive is associated with strategic control of processing, whereas the *episodic buffer* is "a limited capacity system that provides temporary storage of information held in a multimodal code, which is capable of binding information from the subsidiary systems, and from long-term memory, into a unitary episodic representation" (Baddeley 2000, p. 417).

The function of binding multimodal information from diverse systems makes the episodic buffer well suited to serving as a stage for future event simulations. fMRI data from a working memory task that requires integration of spatial and verbal information indicate that medial BA 10 is a candidate site of the episodic buffer, because it is preferentially activated during maintenance of integrated versus unintegrated information (Prabhakaran et al. 2000). Given the proximity of this region to the one in which we documented greater activity for future imagining than remembering, we are encouraged to postulate that medial BA 10 holds together the diverse elements comprising a future event simulation, and may work closely with the hippocampus in constructing the elements that support the full-blown theater production. Exploring the interrelations of these regions constitutes a critical next step for future-oriented research.

ACKNOWLEDGMENTS

Preparation of this paper was supported by grants from the NIA and NIMH to DLS. We thank A. Wong for assistance and M. Bar for comments.

Studying mental states is not a research program for comparative cognition

DOI: 10.1017/S0140525X0700218X

Sara J. Shettleworth

Department of Psychology, University of Toronto, Toronto, Ontario M5S 3G3, Canada.

shettle@psych.utoronto.ca

Abstract: The title of the target article suggests an agenda for research on cognitive evolution that is doubly flawed. It implies that we can learn directly about animals' mental states, and its focus on human uniqueness impels a search for an existence proof rather than for understanding what components of given cognitive processes are shared among species and why.

"What is mental time travel, and is it unique to humans?" As the focus for research on cognitive evolution, this question is doubly flawed. Not only can we never know what other species' mental experiences are like, searching for a yes or no answer to a question about human uniqueness is not a productive way to proceed with research in comparative cognition. This path leads to a quest for an existence proof (just one animal with "it" is enough), followed by endless disputes over whether "it" really was demonstrated. The history of attempts to teach forms of human language to apes (Shettleworth 1998) is evidence enough for this. Far more productive as well as consistent with evolutionary thinking is to ask something like, "What components of process X are and are not shared among what species and why, in evolutionary, functional, and perhaps neurological terms?" Progress in answering such questions is most likely to be made when the process being compared across species is already well understood within at least one of the species in question, human or other animal.

In various places, Suddendorf & Corballis (S&C) do address the difficulty of drawing conclusions about animals' mental experiences, for example, when discussing episodic-like memory in section 3.1. But this is not merely a matter of not having enough evidence yet: Because we can only observe behavior, we can *never* know if animals are mentally time traveling anywhere. Researchers can productively seek no more than functional similarities between human and animal behaviors in analogous situations. A pattern of brain activity (S&C, sect. 2.3) is just another item of function similarity, and one that is a priori denied to species with very different brains from humans.

An instructive example of what is meant by documenting functional similarity of behaviors is research on metacognition in rhesus macaques. Contrary to what S&C suggest in section 4.5, there is a now a rich body of convergent evidence from several laboratories and testing paradigms consistent with these monkeys' being able to monitor both the certainty of their perceptual judgments and the strength of their memories. For example, when memory is poor, monkeys choose to escape tests of memory more often; but when they choose to take the test, they continue to perform well, better than when forced to take it (Hampton 2001; see also Smith & Washburn 2005). Monkeys show this functional relationship immediately when memory is taxed, further indicating that their behavior does not reflect learning to use cues like length of the retention interval. Monkeys' reports of metacognitive certainty transfer across tasks (Kornell et al. 2007), and they behave as if they are using it to control information seeking in naturalistic (Hampton et al. 2004) and operant tasks (Kornell et al. 2007). The availability of multiple convergent measures and more than one testing paradigm also