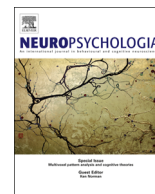




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Reviews and perspectives

Individuals with episodic amnesia are not stuck in time

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ABSTRACT

The metaphor that individuals with episodic amnesia due to hippocampal damage are “stuck in time” persists in science, philosophy, and everyday life despite mounting evidence that episodic amnesia can spare many central aspects of temporal consciousness. Here we describe some of this evidence, focusing specifically on KC, one of the most thoroughly documented and severe cases of episodic amnesia on record. KC understands the concept of time, knows that it passes, and can orient himself with respect to his personal past and future. He expresses typical attitudes toward his past and future, and he is able to make future-regarding decisions. Theories claiming that the hippocampus plays an essential role in temporal consciousness need to be revised in light of these findings.

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Contents

1. Introduction	1
2. Temporal consciousness and semantic drift	1
3. Semantic knowledge of time	2
4. Attitudes about time	3
5. Valuing the future	3
6. Anticipating regret	3
7. Conclusion	4
Acknowledgments	5
References	5

1. Introduction

The idea that episodic memory is required for temporal consciousness is common in science (Dalla Barba & La Corte, 2013; Tulving, 1985; Suddendorf & Corballis, 2007), philosophy (Hoerl, 1999; Singer, 2011), fiction (Nolan, 2000), and everyday life (Hilts, 1996). Related ideas follow naturally: that individuals with episodic amnesia are lost mariners (Sacks, 1970), stuck in time (Roberts, 2002), in a “permanent

present tense” (Corkin, 2013) or “lost in a non-time, a sort of instantaneous present” (La Corte et al., 2011, p. 314).

Yet recent evidence suggests that people with episodic amnesia are not stuck in time. Episodic memory and future thought are dissociable from semantic knowledge of time, attitudes about time, and consideration of future consequences in decision-making. These findings illustrate how little is known about the sense of time in episodic amnesia and suggest that the human sense of time is likely not one thing, but many things.

2. Temporal consciousness and semantic drift

People with extensive hippocampal damage have deficits in remembering past personal experiences (Tulving, 1983; Rosenbaum

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et al., 2005) and imagining future states of the self (Klein et al., 2002; Kwan et al., 2013; Race, Keane, & Verfaellie 2011; Maguire et al., 2010). Yet it is a stretch from this finding to the claim that amnesics are stuck in time or lack “temporal consciousness”.

Dalla Barba and La Corte, for example, justify this leap on the basis of a conversation between Endel Tulving (ET) and KC, who suffered extensive brain damage in a motorcycle accident and has become the definitive case of episodic amnesia. KC’s brain damage includes substantial volume loss in the hippocampus and the parahippocampal gyrus bilaterally, as well as several regions outside of the medial temporal lobe known to play a role in memory. The conversation about time is as follows:

ET: Let’s try the question again about the future. What will you be doing tomorrow? [15 second pause.]

KC: I don’t know

ET: Do you remember the question?

KC: About what I’ll be doing tomorrow?

ET: Yes. How would you describe your state of mind when you try to think about it?

KC [five second pause] Blank, I guess (Tulving, 1985, p. 4)

Asked to explain this remark, KC says, “It’s like being in a room with nothing there and having a guy tell you to go find a chair, and there’s nothing there,” or, “It’s like swimming in the middle of a lake. There’s nothing there to hold you up or do anything with” (Tulving, 1985, p. 4). These remarks are taken to justify the claim that KC and other episodic amnesics lack temporal consciousness (Dalla Barba & La Corte, 2013) and so are trapped in a permanent present (Corkin, 2013). Their life is a “Humean froth,” a “fluttering on the surface” (Sacks, 1970). In this respect, they are like rats and young children (Roberts, 2002).

If temporal consciousness is defined simply as the ability to remember past personal experiences and to episodically imagine future personal experiences, then KC lacks temporal consciousness. Yet the meaning of the term “temporal consciousness” invites semantic drift; the definition of the term creeps away from its original meaning and, without our awareness, comes to denote a far more encompassing set of cognitive faculties. Dalla Barba and La Corte, for example, initially defined temporal consciousness as “awareness of one’s own past, present, and future” (La Corte et al., 2011) and now describe it as, specifically, “a form of consciousness that allows individuals to remember their personal past, to be oriented in their present world, and to predict their personal futures” [Dalla Barba & La Corte, 2013]. Temporal consciousness so defined comprises many cognitive faculties, including many that

are preserved in people with severe deficits in episodic memory and future thought. Because KC has such a complete deficit in episodic memory and future construction, he presents a unique opportunity to assess which aspects of the human sense of time can be preserved even when the memory systems of the medial temporal lobes are severely compromised.

3. Semantic knowledge of time

The above conversation between Tulving and KC is not a full accounting of KC’s temporal competence. Although he has an anterograde semantic deficit, his retrograde semantic memories, including autobiographical details, are intact (Tulving, 1985; Rosenbaum et al., 2005; Westmacott et al., 2001). He knows when he was born, that he went to high school and graduated, and that he visited New Orleans during college. He knows that his brother once lived and now is deceased. In this respect, KC is like other individuals with episodic amnesia who selectively retain semantic but not episodic elements of autobiographical memory (Klein & Nichols, 2012; Van der Linden et al., 1996). Importantly, KC can correctly order these and other notable personal life events on a timeline, though he tends to compress their distance from the present (see Fig. 1). This compression is perhaps explained by the fact that KC consistently underestimates his age by approximately 10 years (Corkin, 2013, Rosenbaum et al., 2005). Nevertheless, KC consciously understands time as a series of events ordered earlier or later than one another, irrespective of any reference to the present. That is, KC understands the B-series (McTaggart, 1908; see Fig. 1), and he knows his life is ordered and located in a B-series.

KC also understands the A-series (contra Hoerl, 1999; but see McCormack, 1999). In the A-series, future events come to pass and then recede, never to return, into the mists of history. Time flows forward; the future cannot affect the past. Consider a recent conversation with KC:²

SR: What is the future?

KC: Events that haven’t happened yet.

SR: What is the past?

KC: Events that have already happened.

SR: Can you change the past?

KC: No.

SR: Can you change the future?

KC: Yes

SR: How?

KC: By doing different things.

SR: Does what happened in the past influence what happens in the future?

KC: Yes.

SR: Does what you do now influence what happens in the future?

KC: I guess so.

SR: Does what you do now change what has happened in the past?

KC: No.

SR: Can something that happens in the future change what has happened in the past?

KC: No.

SR: If an event is in the future, will it *always* be in the future?

KC: No.

SR: Why?

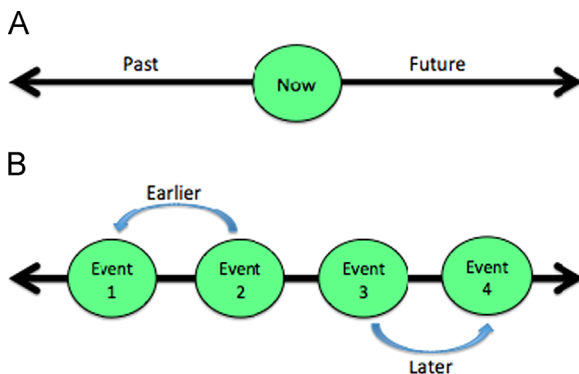


Fig. 1. Two concepts of time: the A-series (time flows; events in the future become present and then past) and the B-series (time as series of events arranged earlier or later than one another).

² Questions in the battery were devised by Carl Craver and Ben Graham and overlap with questions administered to the amnesic subject, D.B., by Klein (personal communication; see Klein, 2013). SR designates R. Shayna Rosenbaum.

KC: Something you don't like doing or wish that you hadn't done.
 SR: Can you name some things a person might regret?
 KC: If someone lost a large sum of money.
 SR: Do you have any regrets?
 KC: I don't think so.
 SR: What do you regret most about your life?
 KC: Nothing – I can't think of anything.
 SR: What are some things a person might do if they feel regretful about something?
 KC: Try to make it right.
 SR: What kinds of things might they do that would show you they are feeling regret?
 KC: You could tell by their tone of voice.
 SR: Do you know Richard Nixon?
 KC: Yes.
 SR: Do you think he/she has any regrets in life?
 KC: I don't think so.
 SR: Do you think your mother has regrets?
 KC: No.
 SR: What are some things that they might regret?
 KC: Nothing.
 SR: Can you describe how these people feel "inside"?
 KC: Mad at themselves.

Regret is a temporally complex emotion, involving imagined future attitudes of the self toward short-term actions that have had intermediate consequences. Yet KC's command of the semantics of regret persists despite his inability to generate a single instance of regret for himself or for near and distant others.

KC's decision-making also shows some evidence of responsiveness to the possibility of future regret. In the Allais paradox, healthy subjects regularly violate the axioms of decision-theory by changing their preferences for the same unit of reward when one of the probabilistic options has a probability in the neighborhood of certainty (Kahneman & Tversky, 1979; Allais, 1953). According to the anticipated regret hypothesis, Allaisian preferences are rational and reflect the value of the anticipated regret resulting from having declined the sure thing for an objectively preferable option. If KC lacks temporal consciousness and is trapped in the present, he should be immune to Allaisian behavior. Yet KC is as susceptible to the Allais effect as are controls (Craver et al., in press).

7. Conclusion

Despite his complete inability to remember past personal experiences and to episodically imagine future experiences, KC maintains semantic knowledge of the A-series and the B-series and can locate his life within each. He disavows hedonistic and fatalistic attitudes. He invests the future with value, comparably to controls. He will wait for a later reward, but only if it is big enough. Finally, KC makes decisions consistent with his sensitivity to possible future regret. It is clearly a stretch to claim that KC lacks temporal consciousness generally.

These findings are especially significant given that KC's episodic memory deficit is the most, or one of the most, severe episodic memory deficits on record, affecting memories across his entire life. That said, many of the findings reported here have been corroborated in other, less severe cases of episodic amnesia. The case DB, for example, can answer semantic questions about the A-series and B-series and can speak meaningfully about the generic, known future (Klein, 2013). Additional cases DG, DA, and HC all score on the low end or below the levels of age-matched controls on ZPTI measures of hedonism and fatalism and perform indistinguishably from controls on measures of inter-temporal choice (Kwan et al., 2013). Findings in

these and other case studies increasingly suggest that such individuals suffer from a deficit in imagination or scene construction that is in many ways independent of the ability to locate events in the past or the future. For example, they have profound deficits in imagining scenes [Hassabis et al., 2007] and retelling semantic narratives [Rosebaum et al., 2005, Rosenbaum, Gilboa, Levine, Winocur, & Moscovitch, 2009; see also Verafallie submitted].

Of course, everybody is trapped in the present. "Mental time travel" and "temporal consciousness" are terse descriptions of work performed by many different cognitive systems that allow humans to deal with time. Because KC neither remembers his personal experiences nor episodically constructs future events, he lacks some tools for orienting in time. Yet it invites semantic drift to claim that KC lacks temporal consciousness or is bound to the present. KC is not stuck in time.

Box 1–The hippocampus: is time of the essence?

Decades of neuropsychological research question the hypothesis that the hippocampus is a time machine or an organ of temporal consciousness (cf. Eichenbaum, 2013; Hassabis et al., 2007; Kwan et al., 2012, 2013; Tulving, 2002; Dalla Barba & La Corte, 2013; Suddendorf & Corballis, 2007). Brenda Milner's early work with the famous amnesic case H.M. inspired the standard consolidation view that the hippocampus is required for the encoding and temporary maintenance of new declarative (consciously accessible) memories (Scoville & Milner, 1957; Squire, 1992). Other influential theories have viewed this structure as serving a more specialized role in representing spatial relations among objects contained within environments (O'Keefe & Nadel, 1978; Bird & Burgess, 2008), episodic memories of personal experiences (Nadel & Moscovitch, 1997), and relational memories more generally (Cohen & Eichenbaum, 1993). Temporal organization of memory, in contrast, has been a prominent feature of theories of frontal lobe function, supported by separate neuropsychological studies by Milner, Petrides, and Smith (1985). The recent discovery of "time cells" in the hippocampus of rats (Eichenbaum, 2013) and macaques (Naya & Suzuki, 2011), together with findings of hippocampal involvement in future thinking and imagining in humans (Addis et al., 2007; Klein et al., 2002; Kwan et al., 2013; Tulving, 1985), gives promise to the idea that the hippocampus is involved in structuring event details within a temporal framework. However, there is parallel evidence of non-mnemonic consequences of hippocampal damage that affect some aspects of perception (Barense et al., 2012), working memory (Rose et al., 2012), and semantic processing (Race et al., 2013). Other research shows that not all types of spatiotemporal sequencing, such as ordering premonitory learned landmarks along routes (Rosenbaum et al., 2000), or future-regarding decisions, such as delay discounting (Kwan et al., 2012, 2013), are affected by hippocampal damage. These findings raise the possibility that the hippocampus plays an associative role in relating or recombining details that is not limited to representing time. It is likely that the hippocampus is concerned with a more fundamental set of processes that integrates personal time with spatial context, perceptual details, and other elements that enable what is experienced by humans as recollection and prospection. What is needed is a more precise set of boundaries that captures those aspects of time with which the hippocampus is concerned, either on its own or within a network of brain regions that includes the ventromedial prefrontal cortex.

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References

- Addis, D. R., Moscovitch, M., & McAndrews, M. P. (2007). Consequences of hippocampal damage across the autobiographical memory network in left temporal lobe epilepsy. *Brain*, *130*, 2327–2342.
- Allais, M. (1953). Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'école Américaine. *Econometrica*, *21*, 503–546.
- Barnese, M. D., Ngo, J. K., & Peterson, M. A. (2012). Interactions of memory and perception in amnesia: The figure-ground perspective. *Cerebral Cortex*, *22*, 2680–2691.
- Bedny, M., Pascual-Leone, A., Dodell-Feder, D., Fedorenko, E., & Saxe, R. (2011). Language processing in the occipital cortex of congenitally blind adults. *Proceedings of the National Academy of Sciences*, *108*, 4429–4434.
- Bird, C. M., & Burgess, N. (2008). The hippocampus and memory: Insights from spatial processing. *Nature Reviews Neuroscience*, *9*, 182–194.
- Boyer, P. (2008). Evolutionary economics of mental time-travel? *Trends in Cognitive Sciences*, *12*, 219–223.
- Cohen, N. J., & Eichenbaum, H. (1993). *Memory, amnesia and the hippocampal system*. MIT Press.
- Corkin, S. (2013). *Permanent present tense: The unforgettable life of the amnesic patient, H.M.* Basic Books.
- Craver, C. F., Green, L., Meyerson, J., Rosenbaum, R. S., Kwan, D., Cova, F., Bourgeois-Gironde, S. (submitted) "An Allais paradox without mental time travel."
- Dalla Barba, G., & La Corte, V. (2013). The hippocampus, a time machine that makes errors. *Trends in Cognitive Sciences*, *17*(3), 102–104.
- Eichenbaum, H. (2013). Memory on time. *Trends in Cognitive Sciences*, *17*, 81–88.
- Green, L., & Myerson, J. (2004). A discounting framework for choice with delayed and probabilistic rewards. *Psychological Bulletin*, *130*, 769–792.
- Hassabis, D., Kumaran, D., Vann, S. D., & Maguire, E. A. (2007). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences*, *104*, 1726–1731.
- Hilts, P. J. (1996). *Memory's ghost: The nature of memory and the strange tale of Mr. M. Touchstone*.
- Hoerl, C. (1999). Memory, amnesia, and the past. *Mind and Language*, *14*, 227–251.
- Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*, 263–292.
- Klein, S. (2013). Making the case that episodic recollection is attributable to operations occurring at retrieval rather than to content stored in a dedicated subsystem of long-term memory. *Frontiers in Behavioral Neuroscience*. <http://dx.doi.org/10.3389/fnbeh.2013.00003> (Published online 1 February 2013).
- Klein, S. B., Loftus, J., & Kihlstrom, J. F. (2002). Memory and temporal experience: The effects of episodic memory loss on an amnesic patient's ability to remember the past and imagine the future. *Social Cognition*, *20*, 353–379.
- Klein, S. B. (2013). The complex act of projecting oneself into the future. *Wiley Interdisciplinary Reviews*, *4*, 63–79.
- Klein, S. B., & Nichols, S. (2012). Memory and the sense of personal identity. *Mind*, *121*, 677–702.
- Kwan, D., Craver, C. F., Green, L., Myerson, J., Boyer, P., & Rosenbaum, R. S. (2012). Future decision-making without episodic mental time travel. *Hippocampus*, *22*, 1215–1219.
- Kwan, D., Craver, C. F., Myerson, J., & Rosenbaum, R. S. (2013). Dissociations in future thinking following hippocampal damage: Evidence from discounting and time perspective in amnesia. *Journal of Experimental Psychology: General*, *142*, 1355–1369.
- La Corte, V., George, N., Pradat-Diehl, P., & Barba, G. D. (2011). Distorted temporal consciousness and preserved knowing consciousness in confabulation: A case study. *Behavioural Neurology*, *24*, 307–315.
- Lebreton, M., Bertoux, M., Boutet, C., Lehericy, S., Dubois, B., Fossati, P., et al. (2013). A critical role for the hippocampus in the valuation of imagined outcomes. *PLoS Biology*. <http://dx.doi.org/10.1371/journal.pbio.1001684> (plosbiology.org).
- Maguire, E. A., Vargha-Khadem, F., & Hassabis, D. (2010). Imagining future and fictitious experiences: Evidence from developmental amnesias. *Neuropsychologia*, *48*, 3187–3192.
- McCormack, T. (1999). Temporal concepts and episodic memory: A response to Hoerl. *Mind and Language*, *14*, 252–262.
- McTaggart, J. M. E. (1908). The unreality of time. *Mind*, *17*, 457–474.
- Milner, B., Petrides, M., & Smith, M. L. (1985). Frontal lobes and the temporal organization of memory. *Human Neurobiology*, *4*, 137–142.
- Nadel, L., & Moscovitch, M. (1997). Memory consolidation, retrograde amnesia and the HC complex. *Current Opinion in Neurobiology*, *7*, 217–227.
- Naya, Y., & Suzuki, W. A. (2011). Integrating what and when across the primate medial temporal lobe. *Science*, *333*, 773–776.
- Nolan, C. dir (2000) *Memento*. Newmarket Films.
- O'Keefe, J., & Nadel, L. (1978). *The hippocampus as a cognitive map*. Oxford: Clarendon.
- Peters, & Büchel (2010). Episodic future thinking reduces reward delay discounting through an enhancement of prefrontal–mediotemporal interactions. *Neuron*, *66*, 138–148.
- Race, E., Keane, M. M., & Verfaellie, M. (2013). Losing sight of the future: Impaired semantic prospection following medial temporal lobe lesions. *Hippocampus*, *23*, 268–277.
- Race, E., Keane, M. M., & Verfaellie, M. (2011). Medial temporal lobe damage cause deficits in episodic memory and episodic future thinking not attributable to deficits in narrative construction. *Journal of Neuroscience*, *31*, 10262–10269.
- Roberts, W. A. (2002). Are animals stuck in time? *Psychological Bulletin*, *128*, 473–489.
- Rose, N. S., Olsen, R. K., Craik, F. I. M., & Rosenbaum, R. S. (2012). Working memory and amnesia: The role of stimulus novelty. *Neuropsychologia*, *50*, 18.
- Rosenbaum, R. S., Priselac, S., Kohler, S., Black, S. E., Gao, F., Nadel, L., et al. (2000). Remote spatial memory in an amnesic person with extensive bilateral hippocampal lesions. *Nature Neuroscience*.
- Rosenbaum, R. S., Kohler, S., Schacter, D. L., Moscovitch, M., Westmacott, R., Black, S. E., et al. (2005). The case of K.C.: Contributions of a memory-impaired person to memory theory. *Neuropsychologia*, *43*, 989–1021.
- Rosenbaum, R. S., Gilboa, A., Levine, B., Winocur, G., & Moscovitch, M. (2009). Amnesia as an impairment of detail generation and binding: Evidence from personal, fictional, and semantic narratives in K.C. *Neuropsychologia*, *47*, 2181–2187.
- Sacks, O. (1970). *The man who mistook his wife for a hat*. Touchstone.
- Sacks, O. (2007). *The Abyss*. *The New Yorker*, *24*, 38–42.
- Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neuropsychiatry and Clinical Neurosciences*, *12*, 103–113.
- Singer, P. (2011). *Practical ethics*. New York: Cambridge University Press.
- Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, Monkeys, and humans: Correction. *Psychological Review*, *99*, 523.
- Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: What is mental time travel, and is it unique to humans? *Behavioral and Brain Science*, *30*, 299–313.
- Tulving, E. (1983). *Elements of episodic memory*. New York: Oxford University Press.
- Tulving, E. (1985). Memory and consciousness. *Canadian Psychologist*, *26*, 1–12.
- Tulving, E. (1993). What is episodic memory? *Current Directions in Psychological Science*, *2*, 67–70.
- Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, *53*, 1–25.
- Van der Linden, M., Bredart, S., Depoorter, N., & Coyette, F. (1996). Semantic memory and amnesia: A case study. *Cognitive Neuropsychology*, *13*, 391–413.
- Wearing, D. (2005). *Forever today: A memoir of love and amnesia*. Corgi.
- Westmacott, R., Leach, L., Freedman, M., & Moscovitch, M. (2001). Different patterns of autobiographical memory loss in semantic dementia and medial temporal lobe amnesia: A challenge to consolidation theory. *Neurocase*, *8*, 37–55.
- Zimbardo, & Boyd (1999). Putting time in perspective: A valid, reliable Individual-differences metric. *Journal of Personality and Social Psychology*, *77*, 1287–1288.