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Mental simulation of future scenarios in transient global amnesia



Aurelija Juskenaitė^{a,b,c,d,1}, Peggy Quinette^{a,b,c,d,1}, Béatrice Desgranges^{a,b,c,d},
 Vincent de La Sayette^{a,b,c,e}, Fausto Viader^{a,b,c,e}, Francis Eustache^{a,b,c,d,*}

^a INSERM, U1077, Caen, France^b UNICAEN, UMR-S1077, Caen, France^c EPHE, UMR-S1077, Caen, France^d Centre Hospitalier Universitaire de Caen, U1077, Caen, France^e Centre Hospitalier Universitaire de Caen, Service de Neurologie, Caen, France

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ABSTRACT

Researchers exploring mental time travel into the future have emphasized the role played by episodic memory and its cerebral substrates. Recently, owing to controversial findings in amnesic patients, this role has become a matter of intense debate. In order to understand whether episodic memory is indeed crucial to future thinking, we assessed this ability in 11 patients during an episode of transient global amnesia (TGA), a unique and severe amnesic syndrome that primarily affects episodic memory. In the first of two experiments, TGA patients were asked to recall personal past events as well as to imagine personal future events, without any guidance regarding content. Under this condition, compared with controls, they provided fewer past and fewer future events, and the latter were less closely related to their personal goals. Furthermore, TGA patients' descriptions of past and future events were scant, containing fewer descriptive elements in total and fewer internal details. In order to assess whether TGA patients might have been basing their future event narratives on their general knowledge about how these events usually unfold, in our second experiment, we asked them to imagine future events in response to short descriptions of common scenarios. Under this condition, inherently eliciting less detailed descriptions, not only were all the TGA patients able to describe common events as happening in the future, but their narratives contained comparable amounts of internal detail to those of controls, despite being less detailed overall. Taken together, our results indicate that severe amnesia interferes with TGA patients' ability to envisage their personal past and future on a general level as well as in detail, but less severely affects their ability to imagine common scenarios, which are not related to their personal goals, probably owing to their preserved semantic memory, logical reasoning and ability to create vivid mental images.

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1. Introduction

The concept of mental time travel as a freestanding ability (Suddendorf & Corballis, 1997; Tulving, 1985) has emerged alongside the observation that amnesic patients display disturbed mental simulation of both past and future events. In the first case study to address this issue, Tulving (1985) reported that Patient KC (at that time referred to as NN), who suffered from severe amnesia following a motorcycle accident, was unable to say what he had been doing the previous day and what he would be doing the

following day. Tulving (1985) therefore concluded that it is episodic memory that makes mental time travel possible, not only into the past, but also into the future. Subsequently, several other case studies featuring informal assessments have also found that patients with amnesia acquired during adulthood are impaired when it comes to evoking past or future events and situating them in time (Andelman, Hoofien, Goldberg, Aizenstein, & Neufeld, 2010; Klein, Loftus, & Kihlstrom, 2002; Tulving, 1985). However, the authors of these studies concluded that while the ability to recall past events and the ability to mentally simulate future events are related, the strength of this relationship is open to question (Andelman et al., 2010).

While informal assessments have mainly focused on appraising amnesic patients' ability to evoke past and future events and quantifying these events, systematic assessments of the content of such events have allowed researchers to gain insight into their qualitative characteristics. For example, a study of eight amnesic

* Corresponding author at: Unité de recherche U1077, "Neuropsychologie et neuroanatomie fonctionnelle de la mémoire humaine", CHU, Avenue de la Côte de Nacre, 14033 Caen Cedex 09, France. Tel.: +33 2 31 06 51 97; fax: +33 2 31 06 51 98.

E-mail address: neuropsych@chu-caen.fr (F. Eustache).

¹ These two authors contributed equally to this study.

patients suffering from adult-acquired amnesia after medial temporal lobe damage showed that they produced fewer episodic details than controls, but a similar number of semantic details when asked to imagine specific past and future events within a supplied framework (Race, Keane, & Verfaellie, 2011). On the strength of a positive correlation between past and future event scores, the authors inferred that the recall of past events and the imagination of future ones involve a common cognitive mechanism sustained by the medial temporal lobe, although they were unable to conclude on its precise nature.

Cognitive and neuroimaging studies of healthy individuals report that the recall of past events and the imagination of future events undergo the same developmental progression, depend on the same variables and are mediated by similar brain regions (for reviews, see, for example, Schacter et al., 2012, and Viard, Desgranges, Eustache, & Piolino, 2012). While there seems to be a consensus on the link between these two abilities, we still do not know whether they are bound together in a relation of dependence or else simply share a common cognitive mechanism.

In support of the latter hypothesis, Hassabis Kumaran, Vann and Maguire (2007) reported that when five patients with amnesia acquired after bilateral hippocampal damage were asked to imagine new scenes in response to short descriptions of common scenarios, they had difficulty producing content details of all types (i.e., spatial references, entities present, thoughts/emotions/actions, and sensory descriptions). The authors argued that the hippocampus supports the process whereby a coherent spatial context is created in which different elements of an experience can be bound, thus influencing not only the recall of past events, but also the mental simulation of fictitious events.

A contradictory conclusion was drawn by Squire et al. (2010) when they examined six patients with adult-acquired amnesia resulting from medial temporal lobe damage that included the hippocampus. No difference was found between patients and controls when it came to the unguided imagination of future events, as both groups provided comparable amounts of internal and external detail, which can be roughly equated to episodic and semantic information. The authors therefore concluded that only the recall of recent past events depends on the hippocampus, and that the recall of remote past events and the imagination of future events rely on other brain regions. However, it remains unknown whether the residual hippocampal tissue in these patients is functional to a degree sufficient to support imagination of new events, as it has already been reported in patients with adult-acquired amnesia (Mullally, Hassabis, & Maguire, 2012). Alternatively, as Maguire and Hassabis (2011) have already underlined, the discrepant results reported in this study can also be explained by the fact that the patients suffered from less severe amnesia, with intact remote memory and only modestly impaired recent autobiographical memory. In addition, this study included older patients and healthy volunteers, who are known to describe past as well as future events in a less detailed manner than young adults do (Addis, Wong, & Schacter, 2008; Gaesser, Sacchetti, Addis, & Schacter, 2011; Madore, Gaesser, & Schacter, 2014; Schacter, Gaesser, & Addis, 2013).

As in research on adult-acquired amnesia, studies of developmental amnesia do not always report convergent results. Nonetheless, difficulties imagining new events generally seem to be less visible in developmental amnesia, probably because the memory impairment is more moderate. In their study, Cooper, Vargha-Khadem, Gadian, and Maguire (2011) reported that 21 children with developmental amnesia displayed an unimpaired ability to imagine new familiar events when a framework was supplied for them. The authors attributed this preserved ability to the patients' semantic memory and/or a degree of functionality in their residual hippocampi. The same conclusion was reached both by Maguire,

Vargha-Khadem, and Hassabis (2010), who showed that Patient Jon's ability to imagine new familiar events when supplied with a general framework was intact, and by Hurley, Maguire, and Vargha-Khadem (2011), who reported similar results on the same task for HC, a patient suffering from developmental amnesia with bilateral hippocampal damage. However, when HC was assessed in an earlier study, using a different method that required the unguided mental simulation of future events, she produced a comparable amount of external detail to controls, but a smaller amount of internal (episodic) detail (Kwan, Carson, Addis, & Rosenbaum, 2010).

Overall, research reports on amnesia are difficult to compare and the symmetry between the ability to recall past events and to imagine new events is not always evidenced. Discrepancies between the results may be due to 1) differences in the patients' neuropsychological profiles, namely the severity of their anterograde amnesia, the extent of their retrograde amnesia, and the point in their lives when the memory disorders were acquired, or 2) the tasks that are used. Amnesic patients are generally asked to mentally simulate new events under three different conditions, that is to say, either in an unguided mental simulation condition, or else in response to short scenario descriptions, which in turn can involve either specific events or familiar/common events. In addition, scoring procedures tend to vary considerably, depending on the authors' hypotheses regarding the cognitive processes underlying the imagination of new events.

Studies of amnesia are, however, particularly useful for tackling questions about the concept of mental time travel and, more specifically, the role played by the ability to remember the past in the ability to imagine future events. Of particular interest here, owing to the purity, severity and recentness of the memory impairment, transient global amnesia (TGA) is a prime model of an acquired memory disorder (Bartsch et al., 2010). This neurological syndrome, of elusive etiology, occurring suddenly and lasting up to 24 h, is characterized by massive episodic memory impairment, but executive functions are considered to be largely spared (Quinette et al., 2003) or only slightly impaired (Jäger, Bänzner, Kliegel, Szabo, & Hennerici, 2009). Moreover, the abrupt onset and recentness of the amnesia mean that there is no cognitive reorganization, and ensure that what looks like retrograde amnesia is not in fact long-lasting anterograde amnesia. Therefore, for the very first time, we assessed the ability of patients in the acute or peri-acute phase of TGA to project themselves into the future.

2. Participants

Eleven patients meeting Hodges and Warlow's (1990) clinical criteria for TGA took part in the study, seven in Experiment 1 and four in Experiment 2. All the attacks were witnessed and reported by an observer, and were characterized by clear-cut anterograde amnesia sparing other cognitive functions, and by the absence of identity loss, neurological symptoms and epileptic features, as well as the absence of recent head injury or active epilepsy. Finally, they all resolved within 24 h. All the TGA patients, admitted to the emergency department of Caen University Hospital, underwent a neurological examination, brain CT scans and electroencephalograms. All of these were normal, except for Patient P05 in Experiment 1, whose scan revealed an occipital meningioma, apparently unrelated to the TGA episode. Patients were examined during the acute or peri-acute phase of TGA, the latter being characterized by the absence of repetitive questioning, reduced temporal disorientation, and slightly improved, but still pathological, performances on free recall tasks. The acute phase, which lasted 4–9 h ($M=6.4$, $SD=2.5$ h) for our patients, was deemed to start when the first signs of amnesia were noticed by a witness,

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