



Using future thinking to reduce temporal discounting: Under what circumstances are the medial temporal lobes critical?



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ABSTRACT

The capacity to envision the future plays an important role in many aspects of cognition, including our ability to make optimal, adaptive choices. Past work has shown that the medial temporal lobe (MTL) is necessary for decisions that draw on episodic future thinking. By contrast, little is known about the role of the MTL in decisions that draw on semantic future thinking. Accordingly, the present study investigated whether the MTL contributes to one form of decision making, namely intertemporal choice, when such decisions depend on semantic consideration of the future. In an intertemporal choice task, participants must select either a smaller amount of money that is available in the present or a larger amount of money that would be available at a future date. Amnesic individuals with MTL damage and healthy control participants performed such a task in which, prior to making a choice, they engaged in a semantic generation exercise, wherein they generated items that they would purchase with the future reward. In experiment 1, we found that, relative to a baseline condition involving standard intertemporal choice, healthy individuals were more inclined to select a larger, later reward over a smaller, present reward after engaging in semantic future thinking. By contrast, amnesic participants were paradoxically less inclined to wait for a future reward following semantic future thinking. This finding suggests that amnesia may have had difficulty “tagging” the generated item(s) as belonging to the future. Critically, experiment 2 showed that when the generated items were presented alongside the intertemporal choices, both controls and amnesic participants shifted to more patient choices. These findings suggest that the MTL is not needed for making optimal decisions that draw on semantic future thinking as long as scaffolding is provided to support accurate time tagging. Together, these findings stand to better clarify the role of the MTL in decision making.

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1. Introduction

Accumulating evidence suggests that the medial temporal lobe (MTL) plays an important role in decision making –particularly in situations where decisions draw on memory for prior experiences (Gupta et al., 2009; Gutbrod et al., 2006; Lee et al., 2012; also see Palombo et al., 2015a for review). Moreover, there is evidence that the MTL may also be important for decision making when choices involve a consideration of future scenarios. For example, the human tendency to engage in temporal discounting (i.e., the propensity to choose a smaller present reward over a larger future reward) is attenuated when individuals first imagine consuming a reward in the context of a future event such as a being at a

restaurant or a sporting event (i.e., when they engage in episodic future thinking; e.g., Benoit et al., 2011; Lin and Epstein, 2014; Liu et al., 2013; Peters and Büchel, 2010; Sasse et al., 2015). This “episodic cueing” effect involves the MTL: The extent to which individuals attenuate their temporal discounting following episodic cueing is correlated with the magnitude of connectivity between the hippocampus and midline prefrontal regions (Benoit et al., 2011; Peters and Büchel, 2010).

Corroborating this finding, we recently found that the attenuation in temporal discounting following episodic cueing that is observed in healthy individuals is not observed in amnesic individuals with damage to the MTL (Palombo et al., 2015b). That is, amnesic participants did not demonstrate the expected shift towards more “patient” choices after they imagined being at a specific event in the future. As expected, the imagined future events elicited from amnesic participants were severely impoverished, in accordance with previous observations (e.g., Maguire and Hassabis, 2011; Race et al., 2011; Tulving, 1985, but see Squire et al.,

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2010). Moreover, these findings were observed regardless of whether amnesic participants had larger MTL lesions or circumscribed hippocampal damage. By contrast, amnesics' performance on a "standard" intertemporal choice task (i.e., one that does not involve episodic cueing) was similar to that of well-matched controls (Palombo et al., 2015b), in line with previous work (Kwan et al., 2012; Kwan et al., 2013).

Intriguingly, a recent study by Kwan et al. (2015), also involving amnesic participants with damage to the MTL or related structures, reported a somewhat different pattern of findings using a similar paradigm. In Kwan et al. (2015), amnesic participants and healthy controls were asked to select events that were either planned or likely to occur in the future (e.g., my granddaughter's birthday party in 1 month); these events were then presented to participants in an intertemporal choice task, such that participants imagined the events prior to making their intertemporal choices. In contrast to Palombo et al. (2015b), they found that the episodic cueing effect in several of their amnesic participants was in the normal range (i.e., was indistinguishable from that of controls) despite impaired performance on an ancillary episodic future thinking task (Kwan et al., 2015). In other words, notwithstanding deficient episodic future thinking, temporal discounting was nonetheless attenuated by episodic cueing to the same degree as controls in a number of their amnesic participants.

This discrepancy in findings between the two studies cannot be accounted for by demographic, neuropsychological, or neuroanatomical characteristics; amnesic groups in the two studies were similar in these respects (also see Palombo et al., 2015c for discussion). Kwan et al. (2015) propose that these differences may instead arise from the nature of the cues used to evoke episodic future thinking: whereas in Kwan et al. (2015), participants imagined real-life events that were either planned for the future or likely to occur (e.g., being at your granddaughter's upcoming birthday party in 1 month from now), in Palombo et al. (2015b), participants imagined generic future events (e.g., being at a street fair in 1 month from now). Thus in Palombo et al. (2015b), the events did not involve pre-determined plans that amnesic participants had for the future. The highly personal nature of the cues used by Kwan et al. (2015) may have enabled amnesic participants to draw on another form of future thinking, namely, semantic future thinking (Atance and O'Neill, 2001). That is, it is possible that even in the absence of episodic future thinking abilities, amnesics could still draw on personal knowledge and reasoning to construct a situation in the future, based on what Klein and colleagues (Klein, 2013; Klein et al., 2002) refer to as "known time" (as oppose to "lived time"), akin to the difference in memory between "knowing" and "remembering" (Tulving, 1985). For example, when cued with "imagine your granddaughter's birthday party in 1 month," amnesic participants may have been able to reason semantically (e.g., based on schema-based knowledge) that this event would require the purchasing of a birthday present for their granddaughter or that bringing their granddaughter a gift would make her happy (because she loves gifts), even if they were not capable of picturing the birthday party unfolding as an event *per se*.¹ We acknowledge that amnesics would also need to use

semantic knowledge to construct a generic future event such as attending a street fair (in Palombo et al., 2015b), but a critical difference is that the personal nature of the Kwan et al. (2015) cues likely fostered the generation of future-oriented information that was more self relevant to amnesics. To the extent that such self-relevant information would involve a greater personal investment in the future-oriented information, it could make the future reward more appealing, increasing the likelihood of amnesic participants selecting the future reward and yielding an attenuation in temporal discounting similar to that observed in the control group.

What follows from this interpretation is the proposal that although either episodic or semantic future thinking can influence decisions (also see Klein, 2013; Schacter et al., 2012), only the former requires the MTL. Indeed, there is some evidence to suggest that amnesics retain some capacity to envision the future semantically (Klein et al., 2002), albeit not to the level of detail of healthy controls (Race et al., 2013). Nonetheless, if amnesics can consider the future semantically, even if at a coarser level, this may be sufficient to elicit greater patience for a future reward in the context of intertemporal choices and may account for the findings of Kwan et al. (2015).

To address this possibility, here we directly examined the effect of semantic future thinking on intertemporal choice in amnesic participants and a comparison group of healthy controls. We designed a novel intertemporal choice paradigm in which future choices were "baited" by using personal semantic cues. More specifically, participants were asked to generate specific items that they would realistically either need or want to purchase in the future (e.g., "If you received \$42 in 4 months what items would you buy with that money?"). Although this type of cue was selected because it does not require imagining a specific event, it is nonetheless possible that healthy, neurologically intact individuals may draw to some extent on episodic processes, as no future thinking task is process pure. However, the goal of the present report was to determine if a shift toward emphasis on personal semantic future thinking could successfully induce more patient choice behavior in amnesics who are otherwise unable to richly engage in episodic future thinking. In light of Kwan et al. (2015), we hypothesized that the use of future-oriented personal semantic cues would attenuate temporal discounting in amnesic participants with MTL damage (as well as in healthy control participants).

2. Experiment 1

2.1. Method

2.1.1. Participants

Nine patients with amnesia (3 women) participated in experiment 1 (see Table 1 for demographic and neuropsychological data). Each amnesic participant's neuropsychological profile indicated severe impairment limited to the domain of memory. Etiology of amnesia included ischemia or anoxia (7 amnesic participants), status epilepticus followed by temporal lobectomy (1 amnesic participant), and encephalitis (1 amnesic participant). Four amnesic participants (P03, P04, P06, P08) had lesions restricted to the hippocampus (see Table 1), one amnesic participant (P01) had a lesion that included the hippocampus and MTL cortices, and two amnesic participants (P02 and P09) had lesions that extended beyond the MTL into anterolateral temporal cortex. Amnesic participants' lesions are presented in Fig. 1, either on CT or MRI scans. Two amnesic participants (P05, P07), who had suffered from cardiac arrest, could not be scanned due to medical contraindications and thus are not included in the figure. MTL pathology for these individuals was inferred based on etiology and

¹ Another way to understand the difference in findings between the two studies is with reference to the fact that the future scenarios in Kwan et al. (2015) were more plausible than the generic events in Palombo et al. (2015b). Given that the hippocampus is more active when imagining implausible versus plausible events (Weiler et al., 2010), the impairment in Palombo et al. (2015b) might reflect greater demands on the hippocampus in that study. Indeed, other work shows that when amnesic participants are asked to select future events pertaining to their lives, they are more prone to select common events (i.e., events that are highly likely to occur in the population) relative to controls (Lenton-Brym et al., 2016). Notably however, the reliance on personal semantic information would be easier for plausible events (as in Kwan et al., 2015) thus leading to the same proposed mechanism described above.

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