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LETTER TO THE EDITOR

How Do Lesion Studies Elucidate the Role of the Hippocampus in Intertemporal Choice?

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To the Editor:

In a thought-provoking article, Boyer (2008) hypothesized that the remarkable human feat of imagining the future may be a crucial driving force in guiding goal-directed behavior. According to his proposal, episodic future thinking serves as a footbrake to offset the natural human tendency to engage in nearsighted behaviors–those that have short but not necessarily long-term gains. In this regard, episodic future thinking may be an intrinsic "look before you leap" mechanism; you may be more likely to take the future into consideration if you first imagine what it would be like. An obvious implication of Boyer's proposal is that episodic future thinking has adaptive value for humans. In support of this idea, two intertemporal choice studies have shown that individuals indeed discount future monetary rewards less (i.e., are more likely to choose a larger future reward over a smaller present reward) when they first imagine consuming these rewards in a future event (e.g., spending the money at a sporting event; Benoit et al., 2011; Peters and Büchel, 2010). These studies also provide evidence that this "cueing effect" is supported by brain structures previously implicated in episodic future thinking, particularly the hippocampus (reviewed in Schacter and Addis, 2009). Beyond the relevance to normal cognition, an additional implication of these findings is that patient populations with reduced episodic future thinking capacity may be more vulnerable to making maladaptive choices. Several recent studies have explored this topic in patients with amnesia due to medial temporal lobe damage and concomitant episodic future thinking deficits (Kwan et al., 2012, 2013, in press; Palombo et al., 2015).

In this issue, Kwan et al. (in press) report a study in which amnesic patients and healthy controls were asked to make intertemporal choices (e.g., \$50 now or \$100 in 1 month) under two conditions: a standard condition and one that involved episodic future thinking cueing. Healthy controls demonstrated the expected attenuation in temporal discounting following episodic future thinking cueing, replicating prior work (Benoit et al., 2011; Peters and Büchel, 2010). Yet, the majority of their amnesic participants also demonstrated this attenuation, despite the fact that many of them performed poorly on an episodic future thinking task. In our own laboratory, we have also investigated the role of episodic future thinking cueing in intertemporal choice in amnesic patients with medial temporal lobe lesions (Palombo et al., 2015). As in Kwan et al., our healthy controls showed the expected attenuation in temporal discounting following episodic future thinking cueing. However, in contrast to their findings (but consistent with our prediction), our patients' intertemporal choices were not altered by cueing.

The discrepant findings between these studies are puzzling, given that the patients in the two studies have broadly similar demographic, neuropsychological, and neuroanatomical profiles. One possibility is that these differences may be due to the nature of the cues used to elicit episodic future thinking. Whereas we asked participants to imagine engaging in specific hypothetical events (e.g., imagine spending \$54 at a bar in 1 month), Kwan et al. asked their participants to imagine real-life plans through the provision of day-planners and calendars (e.g., imagine your granddaughter's birthday party in 1 month). Kwan et al. suggest that the highly personal nature of their cues may have enabled amnesic patients to leverage semantic future thinking instead of episodic future thinking. The notion that decision making can be supported by different types of future thinking, only some of which depend on the hippocampus, is an intriguing possibility that requires future empirical work. Critically, such work will require independent verification of the strategies participants bring to bear on envisioning the future during decision making. To this end, our study examined whether cueing future events in our participants indeed elicited episodic future thoughts (Palombo et al., 2015). We found that it did: Both patients and controls largely provided descriptions of specific events, albeit patients'

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descriptions were highly impoverished. Further, the degree of perceptual detail of these descriptions—a well-established indicator of episodic engagement—accounted for the magnitude of the shift in intertemporal choice following cueing in healthy controls. Kwan et al. (in press) did not query individuals' responses to cueing, but their proposal leads to the prediction that, relative to our cues, their cues should elicit more generic (semantic) details in amnesic patients.

The idea that future-oriented decisions can be supported by a variety of processes may also shed light on another unexpected finding in this literature. Specifically, under standard intertemporal choice conditions (i.e., when no cues are provided), patients with medial temporal lobe lesions consistently perform normally, albeit analytic methods in patient studies have been more limited than those in the broader literature (Kwan et al., 2012, 2013, in press; Palombo et al., 2015). By contrast, a number of studies in rodents have demonstrated that hippocampal lesions lead to impaired (heightened) temporal discounting (Abela and Chudasama, 2013; Cheung and Cardinal, 2005; Mariano et al., 2009; McHugh et al., 2008). We speculate that rodent analogues of intertemporal choice may draw more heavily on episodic-like processes than human studies. Whereas human studies only require the consideration of hypothetical outcomes, animals actually experience the rewards and delays, and thus must draw on experience to guide future choice. Intriguingly, other work has demonstrated that rodent hippocampal cells show a pattern of "forward shifting" firing before animals reveal behavioral choices (Johnson and Redish, 2007), raising the possibility that rodents engage in some form of future cognition that may impact decision making, much as Boyer hypothesized in humans. The joint consideration of human and animal studies of intertemporal choice offers a promising avenue for future work aimed at understanding both the conditions under which the hippocampus contributes to future-oriented decision making and the mechanisms by which it does so. Through their important work involving a human lesion approach, Kwan and colleagues have helped pave a path for undertaking this inquiry.

REFERENCES

Abela AR, Chudasama Y. 2013. Dissociable contributions of the ventral hippocampus and orbitofrontal cortex to decision-making with a delayed or uncertain outcome. Eur J Neurosci 37:640–647.

Benoit RG, Gilbert SJ, Burgess PW. 2011. A neural mechanism mediating the impact of episodic prospection on farsighted decisions. J Neurosci 31:6771–6779.

Boyer P. 2008. Evolutionary economics of mental time travel? Trends Cogn Sci 12:219–224.

Cheung TH, Cardinal RN. 2005. Hippocampal lesions facilitate instrumental learning with delayed reinforcement but induce impulsive choice in rats. BMC Neurosci 6:36.

Johnson A, Redish AD. 2007. Neural ensembles in CA3 transiently encode paths forward of the animal at a decision point. J Neurosci 27:12176–12189.

Kwan D, Craver CF, Green L, Myerson J, Boyer P, Rosenbaum RS. 2012. Future decision-making without episodic mental time travel. Hippocampus 22:1215–1219.

Kwan D, Craver CF, Green L, Myerson J, Rosenbaum RS. 2013. Dissociations in future thinking following hippocampal damage: Evidence from discounting and time perspective in episodic amnesia. J Exp Psychol Gen 142:1355–1369.

Kwan D, Craver CF, Green L, Myerson J, Gao F, Black SE, Rosenbaum RS. Cueing the personal future to reduce discounting in intertemporal choice: Is episodic prospection necessary? Hippocampus (in press).

Mariano TY, Bannerman DM, McHugh SB, Preston TJ, Rudebeck PH, Rudebeck SR, Rawlins JN, Walton ME, Rushworth MF Baxter MG, Campbell TG. 2009. Impulsive choice in hippocampal but not orbitofrontal cortex-lesioned rats on a nonspatial decision-making maze task. Eur J Neurosci 30:472–484.

McHugh SB, Campbell TG, Taylor AM, Rawlins JN, Bannerman DM. 2008. A role for dorsal and ventral hippocampus in inter-temporal choice cost-benefit decision making. Behav Neurosci 122:1–8.

Palombo DJ, Keane MM, Verfaellie M. 2015. The medial temporal lobes are critical for reward-based decision making under conditions that promote episodic future thinking. Hippocampus 25: 345–353.

Peters J, Büchel C. 2010. Episodic future thinking reduces reward delay discounting through an enhancement of prefrontal-mediotemporal interactions. Neuron 66:138–148.

Schacter DL, Addis DR. 2009. On the nature of medial temporal lobe contributions to the constructive simulation of future events. Philos Trans R Soc Lond B Biol Sci 364:1245–1253.