



## Episodic memory processes mediated by the medial temporal lobes contribute to open-ended problem solving

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### ABSTRACT

The present study investigated the contribution of episodic memory processes mediated by the medial temporal lobes to solving open-ended problems: problems for which standard solutions or set procedures for arriving at solutions do not exist. Patients with unilateral temporal lobe epilepsy and excisions (TLE), older adults and control participants were asked to describe detailed solutions to various open-ended, social scenarios. TLE patients and older adults, both having deficits in episodic memory, provided fewer steps *relevant* to the given solution than their comparison group. Segmenting the descriptions into details using the methods of the Autobiographical Interview, we also found that patients with TLE and older adults provided fewer *internal* (episodic) details but a similar number of *external* (semantic) details compared to their control group. These findings are the first to demonstrate that processes underlying episodic memory, in particular those enabling the retrieval of experiential detail and episodic simulation may contribute to open-ended problem solving. Given that we examined groups with medial temporal lobe lesions and known episodic memory dysfunction, these results further suggest that the negative consequences of episodic memory loss resulting from damage to or deterioration of the medial temporal lobes extend beyond that of memory to include other domains, such as problem solving.

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Episodic memory processes allow one to recollect past events, deal with present concerns, and imagine future events. We know a great deal about the psychological processes and neural mechanisms underlying episodic memory (e.g., Eichenbaum, Otto, & Cohen, 1992; Squire, Wixted, & Clark, 2007), but considerably less about the uses to which these episodic memory processes are put in everyday life (but see Pillemer, 2003). This matter is particularly relevant when evaluating the implications of memory loss following brain injury or deterioration for daily activities because it suggests that people with such deficits will also have impairments in areas outside of memory. In this paper, we examine the relation between episodic memory processes and problem solving. We propose that for problems that are not well-defined (open-ended problems which do not have a set path, rule or algorithm to a solution), psychological processes and the underlying neural structures associated with recalling details of past events can help develop effective solutions. Because the medial temporal lobes (MTL) and the hippocampus specifically have been implicated as

crucial for recalling the past and imagining the future (Hassabis, Kumaran, Vann, & Maguire, 2007; Schacter, Addis, & Buckner, 2007), this paper also assesses whether MTL-dependent processes are involved in creating solutions for open-ended problems. To do so, we investigated patients with temporal lobe epilepsy or excisions (TLE) and healthy older adults both of whom have episodic memory dysfunction associated, respectively, with medial temporal lobe lesions or deterioration.

Considerable evidence has demonstrated that the MTLs are the hub of the episodic memory neural network. According to the Component Process Model and the Multiple Trace Theory, the MTLs construct a single, informationally rich memory trace from random co-occurring elements of consciously experienced events (Moscovitch, 1992, 2008; see also Eichenbaum, Yonelinas, & Ranganath, 2007). Detailed recall or re-experiencing of these events is thought to be dependent on the hippocampus and related MTL structures, irrespective of the time since acquisition (Nadel & Moscovitch, 1997). Importantly, the MTL-based processes underlying detailed recollection also allow for the flexible recombination of elements from different experiences, which can be used to construct novel vivid scenes and scenarios (Addis, Wong, & Schacter, 2007; Hassabis et al., 2007; Rosenbaum, Gilboa, Levine, Winocur, & Moscovitch, 2009). Functional neuroimaging studies have shown that autobiographical memory retrieval and imagining future events activate

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a common neural network that includes medial temporal regions (Addis, Moscovitch, & McAndrews, 2007; Addis, Wong, et al., 2007; Szpunar, Watson, & McDermott, 2007). Lesion studies have found that patients with medial temporal damage provide less detailed descriptions of remote personal memories (Viskontas, McAndrews, & Moscovitch, 2000) and of imagined events (Hassabis et al., 2007) than do healthy controls. Also, in comparison with younger adults, older adults typically are poorer at detailed recollection (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002) and event stimulation (Addis, Wong, & Schacter, 2008), which is likely related to hippocampal deterioration associated with aging (Driscoll et al., 2003). Together, these findings and formulations form the basis of the hypothesis that detailed remembering, as supported by the episodic memory system, can contribute to *event simulation*. That is, the very same processes that are used to recombine elements of events to *reconstruct* the past can also be used to *construct* novel scenes, scenarios and future events (Hassabis & Maguire, 2009; Schacter & Addis, 2007; Suddendorf & Corballis, 1997).

We suggest that these event simulation processes may also be used to solve ill-defined, or open-ended, problems by allowing one to simulate possible scenarios to determine the appropriate solution and/or solution paths. Unlike well-defined problems which typically have a single solution that can be reached by applying rules, algorithms, or general scripts, open-ended problems have multiple possible solutions for which there is no specific script or solution path that can be applied (Schraw, Dunkle, & Bendixen, 2006; Williams et al., 2006). Consequently, procedures for solving open-ended problems cannot be stored and retrieved from semantic memory making it likely that solutions to such problems would rely on an event simulation strategy. Supportive evidence for this hypothesis comes from studies that have shown that groups with diminished episodic memory retrieval, such as adults who are depressed (Goddard, Dritschel, & Burton, 1996) and adults who have attempted suicide (Evans, Williams, O'Loughlin, & Howells, 1992; Sidley, Whitaker, Calam, & Wells, 1997), have poor social problem solving skills, as measured by a means-end social problem solving test. These poor problem solving skills relate to their tendency to access over-general autobiographical information rather than specific, context-dependent detailed memories that are the hallmark of recollection (Williams et al., 1996, 2006). Whether this tendency to retrieve over-general autobiographical memory is related to prefrontal or medial temporal underactivity associated in depression is still not clear.

To the best of our knowledge, no study has thoroughly examined the relation between the integrity of recollective processes and the richness of event simulation mediated by a network of brain regions that includes the MTLs in relation to effectiveness in solving open-ended problems. The present investigation examined this by looking at the performance of two cohorts with known difficulties in episodic recollection and/or event simulation processes, individuals with unilateral temporal lobe epilepsy or excisions (TLE) and healthy older adults on a test of open-ended social problem solving. We predicted that the richness of event simulation as measured by the amount of detail specific to an event would correlate with problem solving effectiveness, and that overall performance would be diminished in older adults and TLE patients compared to matched control participants.

Patients with TLE are impaired at tasks that involve episodic memory, particularly recollecting autobiographical memories (Addis, Moscovitch, et al., 2007; St-Laurent, Moscovitch, Levine, & McAndrews, 2009; Viskontas et al., 2000), but they still have normal levels of intellectual functioning and generally intact performance on tests of executive functioning. Also, there is no appreciable difference in autobiographical memory between patients with medial temporal dysfunction who are awaiting surgery and those who have undergone temporal-lobe excisions that include portions of

the lateral temporal neocortex in addition to the medial structures (St-Laurent et al., 2009; Viskontas et al., 2000). Thus, it is likely that any impairment on a problem solving measure is linked to the episodic memory deficits associated with TLE.

We also tested older adults because their deficient autobiographical, episodic memory (Levine et al., 2002), which is associated with medial temporal deterioration (Driscoll et al., 2003), predicts that they would show similar, though milder, problem solving deficits than TLE patients, despite having more life-experience than younger adults. Testing older adults also enabled us to eliminate non-cognitive factors associated with TLE (e.g., effects of seizures and anticonvulsant medication, other mental health issues such as depression and anxiety that some TLE patients may have) that may have contributed to deficient performance.

All participants were administered a test of open-ended social problem solving, the Means-Ends Problem Solving Test (MEPS; Platt & Spivack, 1975). In this test, participants are given the beginnings and ends of ten vignettes that each contain a social problem (e.g., Beginning: moving to a new neighborhood and wishing to make new friends – End: Becoming friends with people in the neighborhood). For each problem, they are asked to describe the middle of the story, that is, to provide the steps necessary to solve the problem. Importantly, the participants are asked to generate ideal solutions to connect the beginning and the end of the stories. They are not to provide any story, but one that effectively connects the problem to the solution (Goddard et al., 1996).

To measure problem solving effectiveness, descriptions were scored according to a method that is standardized for MEPS. The number of steps (means) *relevant* to the given solutions (i.e., end of the vignettes) as well as the total number of steps (means that included both *relevant* and *irrelevant* solutions) was recorded. To characterize the richness of details in the descriptions of the middle of the story (solution path), we used a scoring technique that was initially developed to assess autobiographical memory (The Autobiographical Interview; Levine et al., 2002). This method categorizes details present in scenarios as either *internal*, in that they are specific to the event and likely derived from episodic memory, or *external*, in that they are not specific to the event, and likely derived from semantic memory. Using this scoring procedure in the past, investigators have found a paucity of internal, but not external, details in populations with episodic memory deficits compared to control participants in their descriptions of autobiographical memories of past events (Addis, Moscovitch, et al., 2007; Levine et al., 2002; St-Laurent et al., 2009). Also, investigators have found that poorer episodic memory leads to the generation of fewer internal details on non-mnemonic simulation-based tasks, such as imagining possible future events (e.g., Addis et al., 2008; Rosenbaum et al., 2009). In all, this supports the working hypothesis that processes mediating episodic memory are related to the generation of internal details on tasks such as the MEPS and the prediction that the number of internal details will correlate with the effectiveness of solutions on the MEPS. These scores in turn, will be related to performance on tests of episodic memory that are sensitive to the integrity of the MTL.

Older adults were also administered a battery of neuropsychological tests that examined their executive functioning and memory functioning, as well as a standard version of the Autobiographical Interview (Levine et al., 2002) that assesses past event recollection and which is sensitive to hippocampal integrity. We administered these tests because in older adults, unlike in patients with TLE, episodic memory deficits often appear alongside executive function deficits. If performance on the MEPS correlated with performance on tests of episodic memory, but not of executive function, this would allow us to rule out general, age-related cognitive deterioration as an explanation for their poorer problem solving ability.

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