



## Ill-defined problem solving in amnesic mild cognitive impairment: Linking episodic memory to effective solution generation



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### ABSTRACT

It is well accepted that the medial temporal lobes (MTL), and the hippocampus specifically, support episodic memory processes. Emerging evidence suggests that these processes also support the ability to effectively solve ill-defined problems which are those that do not have a set routine or solution. To test the relation between episodic memory and problem solving, we examined the ability of individuals with single domain amnesic mild cognitive impairment (aMCI), a condition characterized by episodic memory impairment, to solve ill-defined social problems. Participants with aMCI and age and education matched controls were given a battery of tests that included standardized neuropsychological measures, the Autobiographical Interview (Levine et al., 2002) that scored for episodic content in descriptions of past personal events, and a measure of ill-defined social problem solving. Corroborating previous findings, the aMCI group generated less episodically rich narratives when describing past events. Individuals with aMCI also generated less effective solutions when solving ill-defined problems compared to the control participants. Correlation analyses demonstrated that the ability to recall episodic elements from autobiographical memories was positively related to the ability to effectively solve ill-defined problems. The ability to solve these ill-defined problems was related to measures of activities of daily living. In conjunction with previous reports, the results of the present study point to a new functional role of episodic memory in ill-defined goal-directed behavior and other non-memory tasks that require flexible thinking. Our findings also have implications for the cognitive and behavioural profile of aMCI by suggesting that the ability to effectively solve ill-defined problems is related to sustained functional independence.

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### 1. Introduction

Recent evaluations of episodic memory have provided compelling evidence that the function of episodic autobiographical memory is not just to recall the past, but to think about the future and plan for it. This is supported by reports of overlap between retrieving past events and constructing future scenes and scenarios, in terms of the underlying neural activity (Addis et al., 2007; Schacter, 2012) and behavioural performance in healthy adults (Addis et al., 2010; Addis et al., 2008; Anderson et al., 2012) as well as in patients with brain damage or deterioration (Addis et al., 2009b; Hassabis et al., 2007). A common element is the involvement of the medial temporal lobes (MTL). The MTL, and the

hippocampus in particular, are presumed to facilitate episodic remembering by binding together co-occurring details to form the conscious re-experience of that event (Cipolotti and Moscovitch, 2005; Moscovitch, 1995; Nadel and Moscovitch, 1997, 2001). These same hippocampal processes can flexibly recombine details from memories of experienced events, allowing for the creation of novel scenes and future scenarios which simulate episodic memories. It is hypothesized that these simulations also guide goal-directed behaviour (Atance and O'Neill, 2001; Bar, 2007, 2009; Barbey et al., 2009; Szpunar et al., 2013).

In earlier studies we tested the hypothesis that MTL-mediated episodic memory processes that support past event reconstruction and future event simulation also serve as a mechanism for solving ill-defined problems (Sheldon et al., 2011; Vandermorris et al., 2013). Ill-defined problems are those that do not have a set routine or algorithm to reach a guaranteed solution. Rather, there are

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typically multiple ways to solve the tasks (Pretz et al., 2003). Navigating a social situation and planning a vacation are examples of ill-defined tasks. Well-defined or closed-ended problems, on the other hand, are tasks for which there is a guaranteed solution if a set script or solution path is followed. Examples of well-defined tasks are making coffee and solving math problems. While finding the correct solutions to well-defined problems can rely on schemas, scripts or algorithms, which are supported by semantic memory processes, these are not as useful for solving ill-defined problems. Ill-defined problems are more likely to rely on flexible, reconstructive episodic memory processes to help create simulations to examine possible solutions (Sheldon et al., 2011). In support of this hypothesis, we found that populations with known loss of MTL-mediated episodic memory processes, such as older adults and individuals with temporal lobe epilepsy (TLE) with confirmed hippocampal damage, were impaired on a test of ill-defined social problem solving (Platt and Spivack, 1975). That test, known as the Means End Problem Solving (MEPS) test, is composed of ten vignettes, each consisting of a social problem for which a participant is asked to describe verbally the ideal solution. Both populations generated less effective solutions compared to healthy control counterparts. By using a modified scoring procedure taken from the Autobiographical Interview (AI; Levine et al., 2002) to score the MEPS solution descriptions for the amount of episodic content in the simulations, we found that older adults and individuals with TLE generated solutions that had less episodic detail compared to their matched counterparts. The amount of episodic detail in their simulations, and in their autobiographical narratives, was correlated with the effectiveness of their solutions on the MEPS. We replicated and extended these findings in an older adult population by showing that the contribution of these episodic memory processes to effective problem solving was specific to ill-defined tasks (Vandermorris et al., 2013).

The current investigation expands on these findings by examining problem solving in relation to memory processes in amnesic mild cognitive impairment (aMCI). aMCI as a precursor to Alzheimer's disease (AD), is characterized, in early stages, by a selective impairment in episodic memory, indicated by declines on tests of anterograde memory. The extent of this impairment is typically between declines in memory associated with aging and those associated with AD (Anderson et al., 2012; Martinelli et al., 2013; Vandermorris et al., 2013). As with AD, the nature of aMCI memory loss has been attributed to neuroanatomical and physiological changes in the MTL (Masdeu et al., 2005). The present study has a number of theoretical and practical implications. Theoretically, understanding the link between memory processes and higher cognitive tasks like problem solving will add to our understanding of the functions of detailed recollection. On the practical side, we can determine if aMCI episodic memory deficits relate to poor problem solving performance. In addition, the study addresses the controversy over whether aMCI, along with selective MTL-driven episodic deficits (Murphy et al., 2008), is also associated with semantic memory deficits (Dudas et al., 2005; Leyhe et al., 2009) in terms of autobiographical retrieval. Finally, we asked if investigating problem solving in aMCI patients will help elucidate how aMCI impacts activities of daily living (Anstey et al., 2013; Farias et al., 2006; Fauth et al., 2013). By determining whether aMCI negatively affects problem solving, we might be able to provide some insights into how memory conditions relate to real-world tasks such as solving ill-defined problems.

## 2. Methods and materials

### 2.1. Participants

**Participants with aMCI.** Sixteen individuals were recruited from an institutional database of research volunteers and referrals to a private memory clinic. Procedures for identifying individuals as having aMCI were based on standard clinical diagnostic criteria (Petersen, 2004). Inclusion criteria were (a) presence of a self- or informant-reported complaint of cognitive decline, (b) absence of significant difficulty with instrumental activities of daily living by self-report, confirmed by informant-report, if available, (c) presence of objective memory impairment on neuropsychological testing (operationalized as either "typical," > 1 score below  $-1.5 SD$  or "comprehensive," > 2 scores below  $-1 SD$ ; as defined by Jak et al., 2009) in the absence of objective impairment on neuropsychological tests of global cognitive status, attention, processing speed, executive functions, visuospatial ability, and language.

**Control participants.** Sixteen age- and education-matched healthy control participants were recruited from the institutional volunteer database. An initial screening interview ensured that participants were free from neurological or psychiatric illness. Control participants scored within the normal range (i.e.,  $Z$  scores >  $-1 SD$ ) on all measures within the neuropsychological battery (Table 1).

All participants gave informed consent in accordance with the institutional ethical guidelines, and received compensation for their participation.

## 3. Procedure

### 3.1. Neuropsychological measures

In individual test sessions, all participants completed a series of questionnaires and neuropsychological tests. The questionnaires assessed mood and functional status associated with daily living. To measure levels of anxiety and depression, we administered the Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1983), a 14 item questionnaire in which items are endorsed

**Table 1**  
Participant demographic and descriptive statistics.

|   | Control    |           | aMCI       |           | Effect size |
|---|------------|-----------|------------|-----------|-------------|
|   | <i>M</i>   | <i>SD</i> | <i>M</i>   | <i>SD</i> | <i>d</i>    |
| Sex   | 69% Female |           | 38% Female |           |             |
| Age   | 74.4       | 7.4       | 75.1       | 5.7       | −0.11       |
| Education   | 15.1       | 3.0       | 15.0       | 2.9       | 0.04        |
| Estimated premorbid IQ (NART)   | 118.8      | 6.1       | 118.8      | 5.3       | 0.01        |
| Mini-Mental State Exam (MMSE; Maximum score=30)   | 29.5       | 0.7       | 28.4       | 1.2       | 0.99**      |
| Self-reported anxiety (HADS; Maximum score=21)  | 4.8        | 3.2       | 4.4        | 3.5       | 0.10        |
| Self-reported depression (HADS; Maximum score=21)   | 2.6        | 1.7       | 3.3        | 2.6       | −0.31       |
| Self-reported instrumental activities of daily living (Lawton and Brody IADLs; Maximum score = 16)    | 15.1       | 1.2       | 15.0       | 1.5       | 0.10        |
| Informant-reported instrumental activities of daily living (Lawton and Brody IADLs; Maximum score=16) | 15.2       | 0.8       | 14.7       | 1.5       | −0.31       |

Note:  $N=32$ , with 16 in each group. Gender difference is not statistically significant. \* $p < 0.05$ , \*\* $p < 0.01$ .

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