Ill-defined problem solving in amnestic 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 amnestic 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

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 amnestic 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
Sex	69% Female		38% Female		
	M	SD	M	SD	d
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.

on a scale of 0–3. To measure functional status, we administered the Lawton Instrumental Activity of Daily Living Scale (IADLs; Graf, 2009). This questionnaire assesses the ability to complete everyday activities in 8 functional domains such as preparing meals, completing household chores or managing medication. Both the Self-reported and Informant IADLs were administered.

A battery of neuropsychological tests was administered to measure global functioning, executive and memory functions. The National Adult Reading Test (NART) was administered to obtain a measure of premorbid intelligence that was used to equate IQ between the aMCI and control groups (Bright et al., 2002). The Mini-Mental State Examination (MMSE: Folstein et al., 1983), a 30 point screening test, was administered to rule out global cognitive impairment in accordance with this diagnostic criterion of MCI. To measure executive function, we administered the Trail Making Test Part B, the Color-Word Stroop test and the Rey-Osterrieth Complex Figure Test Copy subsection (Lezak et al., 2004). Episodic memory was measured with the Hopkins Verbal Learning Test-Revised (HVLT-R), Wechsler Memory Test-Revised (WMS-R) Logical Memory subtest (Immediate and Delay Recall) as well as the Rey-Osterrieth Complex Figure Test Immediate Recall (Lezak et al., 2004).

3.2. Autobiographical memory and problem solving measures

The Autobiographical Interview (AI; Levine et al., 2002) was used to measure episodic autobiographical memory by quantifying episodic details in past event narratives. The Means-End Problem Solving test (MEPS; Platt and Spivack, 1975) was used to measure ill-defined problem solving by asking participants to describe solutions to social problems.

3.3. The Autobiographical Interview: adminstration

We used an abbreviated version of the AI. Participants were asked to describe, in as much detail as possible, past personal events for two time periods, one recent event (within the last year) and one remote event (before the age of 11). They could choose any event they wished, but they were informed that the event had to be one in which they were personally involved and specific to a time and place (e.g., an event that happened at the beach during one day of a vacation) rather than over an extended period (e.g., the entire week long vacation). Because the specific probe condition described in the standard AI administration does not alter patterns of results (Levine et al., 2002), particularly with respect to age-related profiles, we did not administer this condition to reduce testing time. All responses were audio-recorded and later transcribed for scoring.

3.4. The Autobiographical Interview: scoring

Each transcribed description was scored according to the standard scoring protocol outlined in the AI manual. The descriptions were segmented into details: distinct pieces of information that related an occurrence, thought or observation, often expressed as a phrase or expression. These details were further classified as internal or external. Internal details are pieces of information that pertain to the main event described and are specific to its spatial and temporal context. The number of internal details is the main measure of episodic memory. External details are event details tangential to the main event as well as personal semantic, factual or metacognitive statements. The number of external details measures the contribution of non-episodic processes to recollection, including semantic memory.

Task example: MEPS ill-defined problem

Mrs. C. had just moved in that day and didn't know anyone. Mrs. C. wanted to have friends in the neighborhood.

The story ends with Mrs. C having many friends and feeling at home in the neighborhood. You begin the story with Mrs. C., in her room, immediately after arriving in the neighborhood.

Fig. 1. An example problem solving vignette from the Means End Problem Solving test (MEPS; Platt and Spivack, 1975). Participants are given the beginning and end of a problem and asked to describe in detail the ideal solution path.

3.5. Means-End Problem Solving test: administration

Participants were given a series of vignettes, each containing a problem of a social nature (e.g., making friends in a new neighborhood; Fig. 1). Participants were given the beginning (problem statement; 'Mr. C just moved to a new neighborhood and does not know anybody') and ending (solution; 'Mr. C has friends and feels at home in the new neighborhood') of these vignettes and were asked to "solve" each one by producing a narrative which best connects the beginning to the end. We used an abbreviated version of the MEPS (i.e., the first four of ten items; Goddard et al., 1996; Raes et al., 2005). There are male and female versions of each MEPS problem. The sex of each participant was matched to the sex of the protagonist of the MEPS story. Participants verbally described their solutions and were given as much time as they needed to do so. The solutions were audio-recorded and later transcribed for scoring.

3.6. Means-End Problem Solving test: scoring

To measure effective problem solving, we used the standardized MEPS scoring procedures. Means, or steps taken to move the protagonist through the story, were extracted from each problem solution. These means were classified as *relevant* if they represented logical steps along the path from problem to the given solution, *irrelevant* if the step described was not appropriate for the given vignette solution and as a *non-mean* if the step was not a step at all. We coded for the number of single instances of relevant means, referred to as categorical means, but also the overall number of relevant means, which included multiple instances of a relevant mean (e.g., if there were multiple forms of the mean 'introducing self to neighbors' for the problem 'Mr. C just moved to a new neighborhood and does not know anybody'). We used the number of categorical relevant means to capture effective problem solving, however the same pattern described in the results emerged when we used overall number of relevant means. Irrelevant and non-means were collapsed into one category: non-relevant means.

To measure the amount of episodic detail or richness associated with problem solving, we adapted the scoring procedures from the AI as we have done in previous work (Sheldon et al., 2011). Internal details were used to measure the level of episodic simulation, or detail, present in the problem solutions and external details measured the amount of semantic, off-topic and metacognitive information.

For both the AI and the MEPS, two trained independent raters completed each scoring procedure. The principal rater was blind to group membership. For all measures, inter-rater reliability was within acceptable limits (r's > 0.8).

4. Results

4.1. Neuropsychological test profile

As presented in Table 1, the aMCI and control groups did not differ in terms of age, education, estimated premorbid IQ, as measured by the NART, levels of anxiety, depression, and instrumental activities of daily living scores. Scores on these measures all fell within the normal range (± 1.5 SD), indicating that the tested sample consisted of high functioning individuals. Following the established neuropsychological profile associated with aMCI, as compared to controls, the aMCI participants scored lower on the MMSE (Table 1), performed equivalently on the majority of tests of executive function, with the exception of Trail Making Test part B, and showed specific impairment on tests that measured episodic memory, with the exception of the WMS-R immediate recall subsection (Table 2).

4.2. Autobiographical Interview

Details generated across both recent and remote event narratives were categorized as either internal or external and the total number of these detail types across both memories was compared between the groups. The number of details produced across the two memories was not different ($t(31)=1.31$, $p=0.21$), which justified combining across memory type. A 2 (group) by 2 (detail type: internal versus external) repeated measures ANOVA revealed a main effect for detail type ($F(1,30)=23.5$, $p<0.001$, $\eta^2=0.44$), and an interaction of group by detail type ($F(1,30)=10.05$, $p<0.005$, $\eta^2=.25$). Simple contrasts showed that the controls produced marginally more internal details ($p=0.09$, $d=0.61$) and significantly fewer external details ($p<0.05$, $d=0.79$) than the individuals with aMCI. Controlling for individual differences in detail output, the ratio of internal to total details was compared between the groups, revealing a significant difference ($F(1,30)=17.17$, $p<0.001$, $\eta^2=0.36$). The control group generated a higher percentage of internal details ($M=47\%$; $SE=2.5$) than the aMCI group ($M=30\%$, $SE=3.3$), indicative of a greater degree of re-

Table 2
Group differences on neuropsychological measures between the control and aMCI participant groups.

	Control		aMCI		Effect size
	M	SD	M	SD	d
Attention/Working memory					
Trails A	0.5	1.1	− 0.2	1.2	0.58
Digit span forward	0.6	0.8	0.4	0.9	0.30
Digit span backward	0.6	1.0	0.4	1.0	0.24
Visuo-construction					
Rey figure copy	0.1	1.6	− 0.1	0.6	0.10
Language					
Phonemic fluency (FAS)	1.1	1.1	0.9	1.0	0.24
Semantic fluency (Animals)	0.4	1.3	− 0.2	1.1	0.50
Executive functions					
Trails B	0.8	0.5	− 0.1	0.7	1.39**
Stroop (Victoria) interference	0.4	0.9	0.2	0.9	0.25
Episodic memory					
HVLT-R total recall	0.3	0.8	− 1.1	0.8	1.86**
HVLT-R delayed recall	0.4	0.6	− 1.5	1.0	2.33**
HVLT-R recognition	0.3	0.7	− 1.3	1.1	1.67**
WMS-R LM immediate recall	0.4	1.1	− 0.4	1.3	0.66
WMS-R LM delayed recall	0.7	0.9	− 0.6	1.2	1.19**
Rey figure immediate recall	0.5	0.9	− 0.9	0.9	1.53**

Note: Units of measure are Z scores ($M=0$, $SD=1$), referenced against published age-based normative values. All values are coded such that higher scores indicate stronger performance. HVLT-R=Hopkins Verbal Learning Test-Revised edition. WMS-R=Wechsler Memory Scale-Revised Logical Memory subtest.

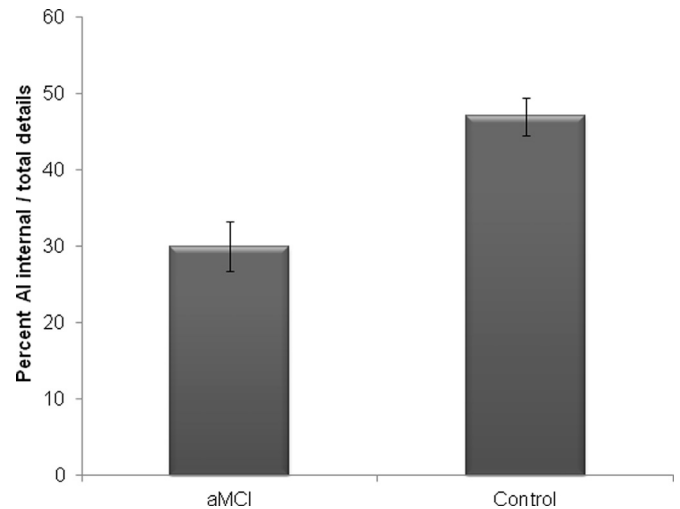* $p<0.05$, ** $p<0.01$.

Fig. 2. The average percent of internal to total details generated during the Autobiographical Interview (AI) for the amnestic mild cognitive impairment (aMCI) and control groups. Error bars represent the standard error.

experiencing when recollecting past events (Fig. 2). These results were not due to differences in output as there were no differences in word count between the aMCI and control participants ($F(1,30)=0.003$, $p=0.96$).

4.3. Means End Problem Solving test

A 2 (group) by 2 (mean type: relevant versus non-relevant) repeated measures ANOVA revealed a main effect for mean type ($F(1,30)=7.18$, $p<0.05$, $\eta^2=0.19$), and an interaction of group by mean type ($F(1,30)=6.71$, $p<0.05$, $\eta^2=0.18$). Simple contrasts showed that the controls produced marginally more relevant means ($p=0.06$, $d=0.68$) and significantly fewer non-relevant means ($p<0.05$, $d=0.85$) than the individuals with aMCI. There was a main effect of diagnosis, such that the aMCI group produced significantly more means overall ($F(1,30)=5.10$, $p<0.05$, $\eta^2=0.15$). Controlling for individual differences in the number of means, the ratio of relevant to total means produced was compared between the groups, revealing a significant difference ($F(1,30)=7.10$, $p<0.05$, $\eta^2=0.19$). The control group generated a higher percentage of relevant means ($M=55\%$; $SE=6.2$) than the aMCI group ($M=34\%$, $SE=5.3$; Fig. 3). These results were not driven by output as there were no differences in word count on the MEPS between the aMCI and control participants ($F(1,30)=0.79$, $p=0.38$).

We also scored the solution narratives for the presence of internal and external details, using an adapted version of the AI. A 2 (group) by 2 (detail type: internal and external) repeated measures ANOVA revealed a main effect for detail type $F(1,30)=5.56$, $p<0.05$, $\eta^2=0.16$), no effect of group ($F(1,30)=0.18$, $p>0.05$) and an interaction of group by detail type ($F(1,30)=5.20$, $p<0.05$, $\eta^2=0.15$; Fig. 4), although simple contrasts of internal or external detail count did not reach significance between the groups. Across participants, we found a significant correlation between the number of relevant means and internal ($r=0.52$, $p<0.01$) but not external details ($r=0.10$, $p=0.60$) and a significant correlation between the number of non-relevant means and external ($r=0.74$, $p<0.01$) but not internal details ($r=−0.16$, $p=0.37$) for the MEPS.

4.4. Across task correlations

Across all participants, there was a significant positive correlation between the proportion of internal relative to total details
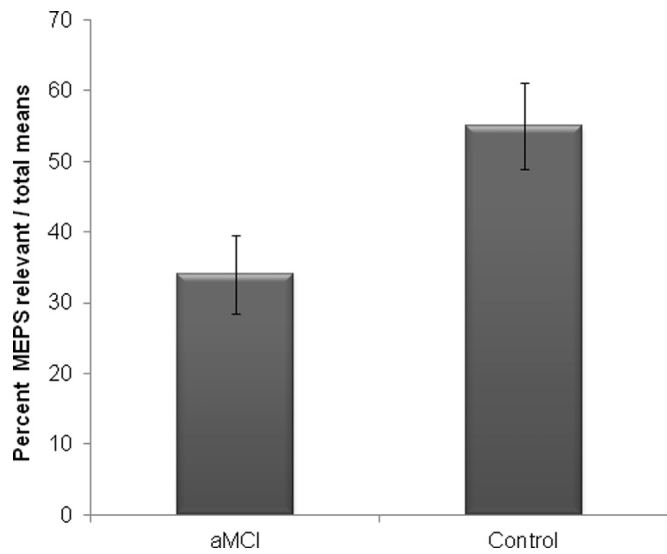
Fig. 3. The average percent of relevant to total means generated during solution generation on the Means End Problem Solving test (MEPS) for the amnestic mild cognitive impairment (aMCI) and control groups. Error bars represent the standard error.
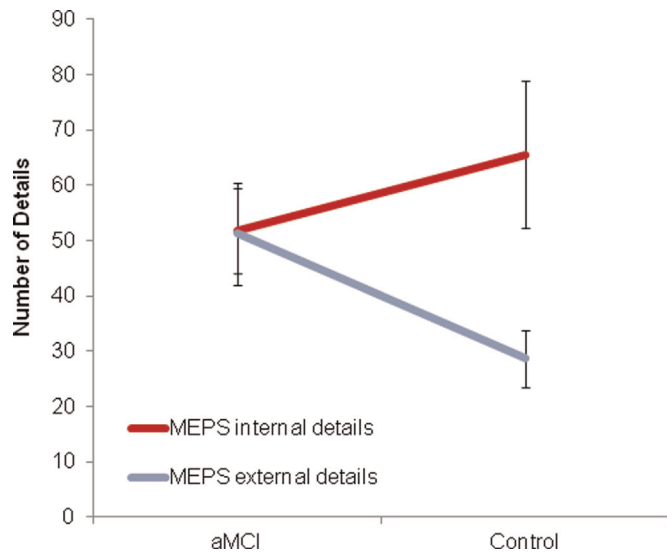

Fig. 5. Illustrated for the amnestic mild cognitive impairment (aMCI) participants, the percent of relevant means to total number of means from the Means End Problem Solving test (MEPS) significantly and positively correlated with the percentage of internal to total number of details.

memory (i.e., HVLT-R and WMS-R delayed recall scores; $r=0.47$, $p < 0.05$), but not between a MEPS score and a composite measure indexing performance on clinical neuropsychological measures of executive functioning (i.e., Trails B, Stroop Color-Word; $r=0.25$, $p=0.17$). Neither of these relationships were significant for the aMCI group alone. Finally, across all participants, there was a significant and positive relation between MEPS scores (proportion of relevant relative to total means) and scores on the given measure of daily living (self-report Lawton–Brody IADLs; $r=0.40$, $p=0.04$; N.B. 4 control participants did not complete this measure), a relationship that was significant for the aMCI group alone ($r=0.52$, $p=0.04$).

Fig. 4. The number of internal and external details during solution generation on the Means End Problem Solving test (MEPS) for the amnestic mild cognitive impairment (aMCI) and control participant groups. Illustrated here is the significant interaction between group and detail type.

5. Discussion

In the current study, we confirmed that aMCI disproportionally impaired the ability to retrieve episodic elements of autobiographical events, as reported previously (Murphy et al., 2008), and showed, for the first time, an accompanying deficit in the ability to simulate effective solutions to ill-defined problems. These findings complement our recent work that implicates MTL-mediated episodic memory processes, those primarily affected in aMCI, in ill-defined problem solving, suggesting that the same reconstructive and flexible episodic memory processes that allow for the reconstruction of past events can be applied to ill-defined problem solving scenarios by aiding in the construction of hypothetical solutions (Sheldon et al., 2011; Vandermorris et al., 2013).

Our results align with reports of aMCI episodic memory impairment from studies that have employed both standardized laboratory measures of memory as well as experimental measures of autobiographical memory (also see, Irish et al., 2011; Murphy et al., 2008). With the AI (Levine et al., 2002), we determined that autobiographical memory loss in aMCI was selective to episodic memory. While the ability to retrieve episodic details of past personal events was impaired, generating non-episodic (external) details, including semantic information, was enhanced in the aMCI group. This suggests that impaired episodic memory in aMCI is accompanied by a greater reliance on semantic memory processes (i.e., more external details), at least for recalling past events. This overreliance on semantic information may reflect a compensatory

generated in their autobiographical narratives and the proportion of relevant relative to total means generated in their hypothetical problem-solving (MEPS) narratives ($r=0.56$, $p < 0.01$; remote $r=0.43$, $p < 0.05$; recent $r=0.47$, $p < 0.01$). This relationship remained significant for the aMCI group ($r=0.69$, $p < 001$; Fig. 5) and control group ($r=0.58$, $p < 0.01$). Statistically controlling for the observed group difference in Trail Making Test part B performance does not change the observed effect for the aMCI group (partial $r=0.60$, $p < 0.01$). Across all participants, we also found a trend towards a significant positive correlation between the number of relevant means on the MEPS and internal details on the AI ($r=0.31$, $p=0.08$) and one between the number of non-relevant means on the MEPS and external details on the AI ($r=0.45$, $p=0.01$).

Across all participants, there was significant correlation between the MEPS score and a composite measure indexing performance on clinical neuropsychological measures of verbal
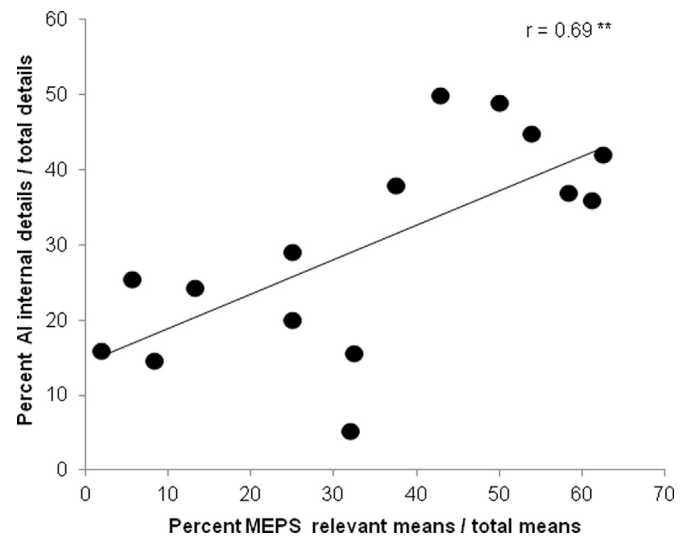
mechanism. Given that this pattern resembles an enhanced version of the profile associated with healthy aging (Addis et al., 2008; Levine et al., 2002), as well as the profile seen in cases of MTL atrophy (St-Laurent et al., 2009), we are confident that the episodic autobiographical memory deficit reported here is due to region-specific loss in the MTL that has come to be associated with aMCI.

To the ill-defined social problems, individuals with aMCI generated solutions that were less effective and less episodically detailed compared to healthy control participants. We also found a significant positive correlation between the episodic richness with which autobiographical memories were retrieved, as measured by the number of internal details, and the effectiveness of the problem solving solutions, as measured by the number of relevant means. This confirmed that problem solving ability is related to episodic autobiographical memory, further supported by the absence of relation between external details on the AI or the MEPS and relevant means on the MEPS. These results support our hypothesis that MTL-supported episodic memory processes critically contribute to ill-defined problem solving (Sheldon et al., 2011; Vandermorris et al., 2013).

While this is clear evidence that episodic memory contributes to ill-defined problem solving, what remains unknown is the precise nature of this contribution. Investigators have credited MTL-mediated episodic memory processes with a role in reconstructing past events as well as in other event-construction tasks, such as future event simulation and scene and event construction (Addis et al., 2008; Mullally and Maguire, 2013; Race et al., 2011; Schacter et al., 2013). It is possible that these same construction processes are put to use for ill-defined problem solving scenarios. Unlike well-defined problems which can rely on schematic or scripted memories to retrieve solutions, ill-defined problems cannot. Thus, solving ill-defined problems can benefit from simulating or constructing hypothetical solutions or solution paths to evaluate their effectiveness (Addis et al., 2009a; Schacter and Addis, 2007; Schacter et al., 2012). Consistent with this interpretation, training to provide more episodic details improves performance on the MEPS in both young and older adults (Madore and Schacter, 2014).

Although we tested one form of ill-defined problem solving, social problem solving, we expect that the nature of these MTL contributions is not based on the content of the problem, but rather the amenability of solution generation to event simulation/ construction. Thus, we predict similar results on tests ill-defined problem solving tasks that are not social, such as financial problems or medical decision making that could also benefit from simulating outcomes. In fact, our results are in accord with investigations that have tested the role of the MTL in other tasks that require flexible integration of information, such as decision-making (Gupta et al., 2009; Gutbrod et al., 2006).

Our findings align with a new theoretical framework that considers the MTL/hippocampal memory system as one that facilitates prediction and planning rather than just remembering (Buckner, 2010; Zeithamova et al., 2012). This framework sets the stage for understanding how the hippocampus supports a variety of tasks beyond problem solving. One possibility is the hippocampus simply recasts past memories to the present to help solve a present problem. Consistent with our proposal, another possibility is that the hippocampus helps create a "memory space" where scenarios of possible outcomes can be simulated via flexible association amongst never-before experienced items (Eichenbaum et al., 1999) or updating older representations with newly experienced information. The latter may help explain why a variety of tasks that require flexible associative thought but not traditional memory processes (e.g., creativity, inferential reasoning, decision-making and problem-solving) implicate the hippocampal system

(Gupta et al., 2009; Gutbrod et al., 2006; Sheldon et al., 2013; Zeithamova et al., 2012).

From a clinical perspective, the fact that the relation between autobiographical memory and ill-defined problem solving was stronger than that between problem solving and standardized measures of episodic memory and not at all for executive processes, suggests that an assessment of autobiographical memory could be considered in the evaluation of individuals with aMCI. Moreover, employing rehabilitative strategies to support autobiographical memory retrieval may add value to interventions aimed at maintaining independent living in individuals with aMCI (Hewitt et al., 2006; Troyer et al., 2008). The results of this study have implications for describing the cognitive, behavioural and functional profiles of aMCI. Amnestic MCI is associated with subtle real-world deficits in daily living (Jefferson et al., 2008; Yeh et al., 2011) and the extent of decline in everyday functioning marks the transition from MCI to dementia. Recently, it was suggested that the memory deficits associated with MCI contribute to difficulties in daily activity (Schmitter-Edgecombe et al., 2012), although the precise way in which these memory deficits interact with functional status in daily life has yet to be resolved. (N.B., Our aMCI group did not differ from the control group on the measure of daily functioning, likely due to limited sensitivity of the test.) Based on our results and in particular the significant relation between measures of problem solving and reports of activities of daily living, we hypothesize that the problem solving deficits associated with aMCI memory deficits are one manner in which cognitive processes impact daily living. Indeed, daily living is full of ill-defined problem solving scenarios. We are constantly navigating situations that are ambiguous ('What should I make for dinner that is cost effective and tastes good?'; 'How should I approach the individual who upset me at the coffee shop?'; 'What should I do for my birthday next week?'). An inability to effectively approach these scenarios due to impairment in simulating optimal solutions is a likely candidate for the link between cognitive and functional status in aMCI. In this respect, tests of ill-defined problem solving may be a stronger indicator of functional decline than self-report, and training people to use detailed episodic simulation (Madore et al., 2014; Madore and Schacter, 2014) may have a beneficial effect on the quality of life of people with aMCI or with comparable memory disorders.

6. Conclusion

Solving problems that are ill-defined and ambiguous requires different cognitive mechanisms from solving problems that are well rehearsed and can rely on scripts and schemas. Here, we show that the same MTL-mediated processes that support recollecting the episodic elements of a past event also support creating effective solutions to ill-defined problems. These results contribute to our understanding of detailed recollection by showing that solution generation is one of its functions, which fits well with contemporary views of hippocampal contributions to flexible cognition (Rubin and Umanath, 2014). By illustrating this link in individuals with aMCI, we illuminate a potential contribution of episodic memory loss that results from MTL impairment to functional independence and daily activity. This information can be used to motivate future therapeutic decision-making for aMCI populations and others with related memory deficits.

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