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ORIGINAL INVESTIGATION

Global impairment of prospective memory following acute alcohol

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Abstract
Rationale Whilst the deleterious effects of alcohol on retrospective remembering have been widely documented, no study has yet objectively determined alcohol's effects on prospective memory (PM)—remembering to do something in the future.
Objectives With this aim, the present study determined the acute effects of alcohol upon PM using a laboratory measure that simulates the PM tasks in everyday life—'Virtual Week'—both (a) in its standard form with regular, irregular, event-based and time-based PM tasks; and (b) an adapted version which enabled exploration of how future event simulation at encoding impacted upon subsequent PM.
Methods Forty healthy volunteers were administered 0.6 g/kg ethanol or a matched placebo in a double-blind fashion and completed the two versions of Virtual Week along with prose recall (to tap retrospective memory) and an executive function task.
Results Alcohol acutely produced global impairments across all (regular, irregular, event-based and time-based) PM tasks. It also produced impairments of episodic memory which positively correlated with PM performance of irregular tasks. Future-event simulation tended to enhance PM in the placebo but not in the alcohol group.
Conclusions These findings on an objective measure of PM suggest that 4–5 units of alcohol will compromise PM abilities in everyday life.

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Introduction

Memory impairment is a robust acute effect of the world's most popular drug, alcohol. Numerous studies have shown its effects to range from mild deficit at low doses to 'blackout' at high doses (for reviews see Curran and Weingartner 2002; White 2003). When information or events occur while an individual is intoxicated, their subsequent episodic memory for them is reduced. Acutely, alcohol can also impair executive functions like planning and decision-making (George et al. 2005; Weissenborn and Duka 2003). Neurocognitive dysfunction in heavy, dependent users is also well documented with deficits observed in problem-solving and decision-making as well as episodic memory (e.g. Bechara et al. 2001; Leckliter and Matarazzo 1989). Surprisingly, research to date has virtually ignored the acute and chronic effects of alcohol on one of the most clinically relevant aspects of memory: prospective remembering.

Most of our acts of everyday forgetting reflect prospective memory (PM) failures—not remembering to do something in the future—such as taking medication on time, collecting dry-cleaning or doing something we promised to do. Prospective memory failures cause more deficits in daily living than retrospective memory failures (Smith et al. 2000) and may be an important factor in the clinical management and rehabilitation of alcohol-misusing patients (Kurtz et al. 2001).

Successfully remembering to do something in the future requires 'mental time travel' (Tulving 1983; Tulving 2005) since performing a PM task implies not only the recall that

something should be done in the future (i.e. 'I must do something at 4 pm'), but also of the content of the action (i.e. 'I must call the plumber at 4 pm'; Cohen et al. 2001; Brandimonte et al. 1996; McDaniel and Einstein 1992). Prospective memory tasks also require an individual to recall the action at a designated future time without an 'instruction' to remember (Einstein and McDaniel 2005; Lockhart 2000), suggesting that planning is essential to successful prospective remembering. Prospective memory is thus dependent upon two key processes: retrospective memory and executive planning (Cohen et al. 2001; Craik 1983; Kliegel et al. 2003; McDaniel et al. 2008).

It is important to differentiate between *time*-based and *event*-based PM tasks (Einstein et al. 1995; McDaniel and Einstein 1992). Time-based tasks require an individual to carry out an action at a specific time (e.g. making a phone call at 4 pm), so that the required behaviour is reliant upon self-initiated mental activities (i.e. clock checking). In event-based tasks, in contrast, the required behaviour is prompted by an external cue (e.g. remembering to buy milk when going shopping). It is also useful to make the distinction between regular and irregular PM tasks. Regular tasks are those that occur during habitual activities (e.g. taking medication at 6 pm every day), while irregular tasks are the occasional tasks of everyday life (e.g. returning a DVD on the way home, Rendell et al. 2007b). Irregular tasks place a greater load on retrospective memory than regular tasks (Kliegel et al. 2008). Research investigating subjective episodic memory complaints in relation to retrospective versus prospective remembering indicates that PM tasks are more sensitive in detecting actual impairments in episodic memory than retrospective tasks (Mantya 2003).

To date, no study has objectively investigated either the acute or chronic effects of alcohol on PM. Three studies have assessed subjective ratings of PM (using the Prospective Memory Questionnaire—PMQ; Hannon et al. 1995). These report that excessive alcohol use by teenagers (Heffernan and Bartholomew 2006) and chronic heavy alcohol use in adults (Heffernan et al. 2002) increases self-reported PM failures; similarly, a web-based PMQ study reported PM failures increased with level of self-reported alcohol use (Ling et al. 2003). Clearly, PM self-reported on a questionnaire may bear little relation to actual PM performance (e.g. Rendell et al. 2007b).

The first aim of this study, therefore, was to directly assess the effects of two doses of alcohol on PM using an objective measure of PM that closely represents the types of PM that actually occur in everyday life: the Virtual Week task (Rendell and Craik 2000; and for a review of the task, see Rendell and Henry 2009). This task was specifically chosen because it allows the investigation of the different types of PM tasks in daily life (regular, irregular, event-based and time-based). By also assessing acute effects on executive functions and retrospective memory, we aimed to elucidate the mechanisms underpinning alcohol's effects on PM. We used a 0.6 g/kg dose of alcohol because it would impair memory while leaving executive planning intact (Finn et al. 1999; Townshend and Duka 2002).

In a recent article, Atance and O'Neill (2001) have suggested that the planning component of prospective remembering might be a possible link between future-event simulation (FES), or 'episodic future thinking' (Schacter and Addis 2007), and PM. It is proposed that FES might be especially important in the process of developing a mnemonic that will allow an individual to remember an intended action in the future. Further, in a recent review, Schacter et al. (2008) similarly suggest that mentally simulating the context in which a PM action will occur may aid successful prospective remembering. Our second aim was to shed some light on this issue by addressing the role of FES in prospective remembering.

We predicted that PM performance would be improved by associating an intention with the specific visual–spatial context in which it would be carried out (e.g. associating the intention 'returning a DVD on the way home' with the actual street and the particular shops passed on the way home). It would seem that one effective mnemonic would be to 'pre-experience' the events in which one is likely to engage in the future. Following this line of thought, we suggest, as others have (Atance and O'Neill 2001; Schacter et al. 2008) that FES might facilitate successful prospective remembering through the association of an intention with the specific visual–spatial context in which intention-completion is likely to take place. We set out to investigate this using a novel, adapted version of the standard Virtual Week that explicitly prompted participants to mentally simulate an intended action at the moment of encoding. For comparison, (a) a rehearsal condition was included, in which participants were asked to verbally rehearse the intended action at encoding instead of mentally simulating it, as well as (b) a standard condition in which participants were not given any strategy at encoding. We predicted that, in the placebo group, simulating the environment in which intention-completion will take place would facilitate encoding and retrieval on event-based tasks (in which intention retrieval is prompted by an external cue in the environment) as opposed to time-based tasks.

Method

Participants

Forty native English speakers (20 females) aged 18–35 were recruited via advertisement from the undergraduate and postgraduate population at University College London. The

study was approved by the UCL ethics committee and participants gave written, informed consent prior to taking part in the experiment. Participants could only take part in the study if they were social drinkers (average weekly consumption 2–14 units). The CAGE alcohol screening questionnaire (Ewing 1984) was used to screen individuals for problematic drinking and participants with a score of two or more were excluded.

There were no group differences in age, number of years in education, alcohol usage or alcohol binge scores (see demographics and trait scores in Table 1).

Design

In a double-blind independent group design, males and females were randomly assigned to either the placebo or the alcohol condition (n=20; ten women in each group).

Alcohol administration

Alcohol was administered at a dose of 0.6 g/kg. Following Knowles and Duka's (2004) procedure, 90% ethanol was diluted with tonic water (Schweppes Ltd., Uxbridge, UK), equally divided into 10×50 ml portions and mixed with two drops of Tabasco sauce (McIlhenny Co., Avery Island, Louisiana, USA) to mask the taste of alcohol. The placebo beverage consisted of 10×50 ml portions of tonic water and Tabasco sauce only. Participants consumed the ten beverages at 3 min intervals in the presence of the experimenter. To maintain the level of alcohol over the entire testing period of 90 min, participants were given three top-up drinks containing either a 0.1 g/kg dose of alcohol each or a matched placebo drink. Each top-up drink was divided into two 50 ml portions and administered at the times shown in Table 2, which pilot work had shown maintained steady blood alcohol concentration (BAC) levels over the period of testing.

Procedure

On arrival at the laboratory, participants gave informed consent and completed the Alcohol Usage Questionnaire (AUQ) and a mood rating scale. A baseline BAC measure was taken to ensure that participants were sober and then they carried out the assessments detailed below in the order given in Table 2.

Table 1 Means (SD) for demographics across treatment groups

	Placebo	Alcohol
Age	25.15 (3.84)	25.30 (3.44)
Years in education	16.05 (1.88)	16.00 (1.59)
AUQ score	36.15 (17.42)	36.50 (24.33)
AUQ binge score	4.75 (13.47)	4.50 (18.90)

Table 2 Procedure: tasks and measures performed with corresponding times (min)

Time (min)	Tasks and measures
0	AUQ
	Prose recall 1 immediate recall task
	Initiation of alcohol administration (0.6 g/kg)
30	End of alcohol administration period
40	BAC 1=0.50 (±0.22)
	Three days of the standard Virtual Week task
70	Top-up drink 1 (0.1 g/kg)
80	BAC 2=0.59 (±0.21)
90	Top-up drink 2 (0.1 g/kg)
	Tower of London
	Prose recall 2 immediate recall task
100	BAC 3=0.67 (±0.21)
	Adapted Virtual Week: day1
110	Top-up drink 3 (0.1 g/kg)
	Adapted Virtual Week: day2
120	BAC 4=0.69 (±0.21)
	Adapted Virtual Week: day3
130	Delayed recall tasks for prose recall 1 and 2
140	Guess on treatment
	Debriefing and payment

Assessments

Standard Virtual Week (Rendell and Craik 2000)

The present study used a computerised version of Virtual Week (as used and described in Rendell et al. 2009) that closely resembled the original version (see Rendell and Craik 2000, and for full description and review of the task see Rendell and Henry 2009). Virtual Week is a laboratory measure of PM that was designed to tap prospective remembering in everyday life. It consists of a virtual board game around which participants move at the roll of a dice, with each circuit of the board representing a day. As participants move the token around the board, they are required to make choices about daily activities and remember to carry out lifelike activities (prospective memory tasks). Virtual Week allows the assessment of the different types of PM failures. Each day includes (1) four regular tasks, which are tasks that occur during normal duties (two of which are time-based, *take asthma medication* at 11 am and 9 pm; and two of which are event-based, *take antibiotics* at breakfast and dinner); (2) four irregular tasks, which simulate occasional tasks of everyday life (two of which are time-based and two of which are event-based), examples are 'drop dry-cleaning in when shopping' and 'phone a plumber at 4 pm'; (3) two time-check tasks, which require the participant to break set from board game activity and

monitor real-time on a stop-clock to indicate when a specific time period has passed. Participants do not physically undertake the tasks, instead when a task is due, they are required to click on a perform task button to display a list of tasks including distracters, and then select the task from the list. Participants were required to complete 3 days of the Standard Virtual Week.

There is considerable evidence for the reliability of Virtual Week with split-half reliability ranging from 0.84 to 0.94 in nonclinical sample of younger and older adults (Rose et al. 2007) and split-half reliability of 0.74 in a clinical group with schizophrenia (Henry et al. 2007). There is also evidence of the validity with Virtual Week shown to be sensitive to the effects of ecstasy and methamphetamine use (Rendell et al. 2007a, 2009), various forms of pathology (Henry et al. 2007, Kardiasmenos et al. 2008; Rendell et al. 2007b; Rendell and Henry 2009) as well as normal and abnormal adult ageing (Rendell and Craik 2000; Will et al. 2009), and for a review of the psychometric properties of Virtual Week, see Rendell and Henry (2009).

Adapted Virtual Week: future-event simulation in PM

Virtual Week was adapted so as to allow the investigation of the role of FES in prospective remembering. Participants were asked to complete three additional days of Virtual Week. Day 1 was a standard day of the task (standard condition). For day 2 and day 3, participants were given two different strategies (one for each day) during the encoding stage of the PM task instructions for irregular time-based and event-based tasks. They were instructed to either verbally rehearse out loud (rehearsal condition) each of the PM tasks for 10 s, or to simulate (simulation condition) each of the intention-completion PM scenarios for 10 s. The rehearsal and simulation conditions were counterbalanced across day 2 and day 3, while the standard condition was always given on day 1 to block carry-over effects from the rehearsal or simulation conditions.

Participants still had to complete Virtual Week's regular time-based and event-based tasks but no strategy was given for these, as participants had learned them during the standard Virtual Week task (these tasks indeed remain the same every 'day' of the week). Time-check tasks were excluded from the adapted Virtual Week task as rehearsal or the simulation would have prevented simultaneous monitoring of the stop-clock.

In accordance with the literature on episodic simulation of future events, which indicates that the phenomenal characteristics of the mental representation of a scenario might be looked at as an index of episodic FES (see D'Argembeau and Van der Linden 2004, 2006; Szpunar and McDermott 2007), in the simulation condition, participants were specifically instructed to imagine events in the most precise way possible, including as many sensorial details as possible. They were asked to imagine the sequence of events, the people and the objects that could be present and the environment in which the event takes place. Participants were also specifically instructed to set the event in their own everyday life (e.g. to imagine the supermarket where they usually shopped). They were then asked to rate (on a scale of 1–5) the vividness of the images they had simulated, as well as the degree to which they felt like they were actually 'living the experience'.

Executive planning abilities (Tower of London-Drexel, Culbertson and Zillmer 2001)

The standard Tower of London was administered. The task, originally developed by Shallice (1982), taps higher-order problem solving and specifically executive planning abilities. The following Tower of London scores were computed: number of moves to solve the test items; number of test items solved in the minimum number of moves; count of rule violations constraining test performance; number of test items requiring more than 60 s to complete; time from the presentation of the test item to the first problem-solving move; time interval between the initiation of the first move to the solution of the test item; and initiation time plus execution time.

Prose recall (Rivermead Behavioural Memory Test: Wilson et al. 1985)

The prose recall task is a subtest of the Rivermead Behavioural Memory Test and was chosen as an ecologically valid measure of verbal memory (immediate recall) and episodic memory (delayed recall). Two versions were administered. For each of them, participants listened to a pre-recorded short prose passage similar to a news bulletin on the radio. Participants were asked to recall each story immediately after presentation and then both stories at the end of the test session.

Manipulation check

To check the effectiveness of double blinding, participants and the experimenter made a guess on which treatment condition the participant had been assigned to (alcohol or placebo) and to rate the certainty of their guess on a scale of one (not certain at all) to five (extremely certain).

Alcohol Usage Questionnaire (AUQ, Mehrabian and Russell 1978)

The AUQ is a 12-item questionnaire designed to provide an accurate measure of an individual's usual alcohol drinking

habits. Variables include the amount of wine, beer and spirits consumed in a typical week as well as speed of drinking. A score for binge drinking was also extracted (see Townshend and Duka 2002).

Statistical analysis

All data analysis was conducted using SPSS Version 11.0. Repeated measures ANOVA with between participants factor of treatment group (alcohol, placebo) was used for Virtual Week measures with type PM task as a within subjects factor. Post hoc paired samples *t* tests were Bonferroni-corrected.

Results

Blood alcohol concentration (BAC)

The mean (±SD) BAC at 40, 80, 100 and 120 min are reported in Table 2.

Manipulation check

Chi-square analysis of participants' guess on treatment showed a significant difference between correct/incorrect responses (χ^2 (1, N=40)=8.10, p<0.01) with a mean confidence rating of 3.8±1.02 out of 5. Analysis of the experimenter's guess on treatment also showed a significant difference between correct/incorrect response (χ^2 (1, N=40)=25.60, p<0.001) with a mean confidence rating of 3.53±1.38 out of 5, thus confirming that both participants and experimenter guessed correctly most of the time.

Standard Virtual Week

A mixed 2×3 ANOVA was applied to the proportion correct on the PM tasks with a between groups factor of *treatment group* (alcohol, placebo) and the within-groups factor of *PM task* (regular, irregular, time check). There were significant main effects of both treatment [F(1, 38)= 11.22, p=0.002, η^2=0.228] and PM task [F(1, 38)=25.49, p<0.001, η^2=0.401] but no interaction. As seen in Fig. 1, the main effect of treatment reflected poorer PM performance following alcohol compared to placebo across all three tasks. Post hoc paired samples *t* tests (Bonferroni-corrected alpha was 0.017) revealed that the main effect of PM task was attributable to poorer performance on the irregular [t(39)=7.34, p<0.001, with Cohen's d=1.47; Cohen (1988) defines effect sizes of 0.2 as small, 0.5 as medium and 0.8 as large] and time-check [t(39)=5.46, p<0.001, d=1.08] tasks compared to the regular task, but no differences between the irregular and time-check tasks.

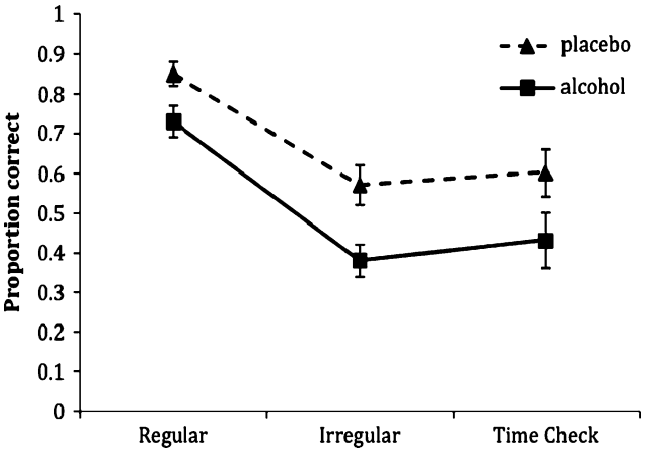

Fig. 1 Proportion correct on standard Virtual Week task by treatment group on time check versus irregular versus regular (*bars* represent standard errors)

A 2×2 mixed ANOVA of time- versus event-based tasks yielded a significant main effect of treatment [F(1, 38)= 14.32, p<0.001, η^2=0.274], but no interaction, again reflecting poorer performance across both tasks following alcohol compared to placebo.

Future event simulation Virtual Week

A mixed 2×2×3 ANOVA was applied to the proportion correct on the irregular PM tasks in second testing phase. The between groups variable was *treatment group* (alcohol, placebo) and the within groups variables were *PM target* (event-based, time-based) and *strategy* (standard, rehearsal, simulation).

The analysis yielded a significant three-way interaction between treatment group, PM target and strategy [F(2, 76)= 3.52, p=0.034 , η^2=0.085]. There was also a significant main effect of treatment group [F(1, 38)=5.46, p=0.025 , η^2=0.126] and a trend towards a main effect of strategy [F(2, 76)=3.01, p=0.055, η^2=0.073].

To explore the three-way interaction, paired samples *t* tests (Bonferroni-corrected alpha was 0.008) were conducted within the alcohol and placebo groups. There were no significant differences between event- and time-based tasks for any of the three strategies in the alcohol and placebo groups. Although not significant following Bonferroni correction, in the placebo group, there was a trend for improved performance under the simulation strategy [t(19)= 2.52, p=0.021, d=0.68, a moderate effect size], reflecting better performance for event-based tasks following the simulation strategy than time-based tasks (Fig. 2 a, b).

Ratings of vividness and 'impression of living the experience' of imagery

Due to ceiling effects, no group differences were found in ratings of vividness and impression of living the experience

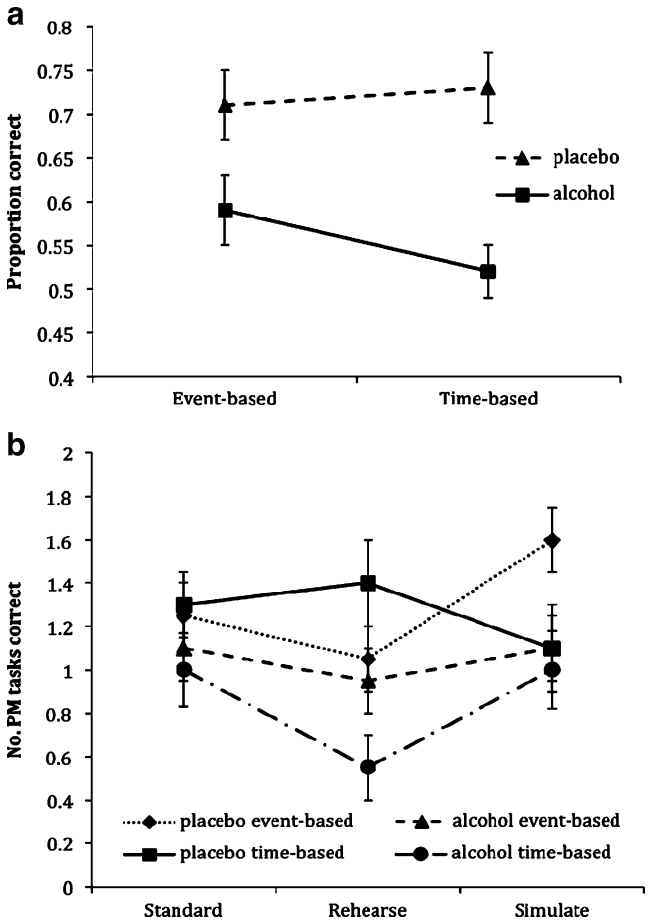

Fig. 2 **a** Group means for the proportion of event- and time-based tasks correct on the adapted Virtual Week task (*bars* represent standard error). **b** Group means for number of correct PM tasks on the adapted Virtual Week task by encoding condition (*bars* represent standard errors)

of imagery during FES, with a mean (SD) vividness rating of 3.63 (±0.53) in the alcohol group and 3.63 (±0.59) in the placebo group, and a mean impression of living the experience rating of 3.40 (±0.71) in the alcohol group and 3.25 (±0.68) in the placebo group.

Tower of London

No differences between the alcohol and the placebo group were found for any of the outcome measures of the Tower of London task (Table 3).

Prose recall

A 2×2×2 mixed ANOVA was applied to the prose recall data. The between groups variable was *treatment group* (alcohol, placebo) and the within groups variables were *delay* (immediate, delayed) and *time* (pre-drink, post-drink). This yielded a significant 3 way interaction between treatment group, delay and time [$F(1, 37)=7.28$, $p=0.01$, $\eta^2=0.164$].

Table 3 Mean (SD) scores for the measures of the Tower of London across treatment groups

	Placebo	Alcohol
Total number of moves	24.40 (16.03)	27.20 (13.75)
Solved in minimum moves	5.05 (2.48)	5.10 (2.10)
Number of rule violations	0.25 (0.55)	0.30 (047)
Number of time violations	0.60 (0.88)	0.70 (1.42)
Total initiation time	101.50 (50.03)	126 (128.56)
Total execution time	296.15 (71.26)	298.25 (155.42)
Total problem-solving time	396.75 (112.50)	424 (277.75)

There was also a time × group interaction [$F(1, 37)=6.03$, $p=0.019$, $\eta^2=0.14$] and main effects of treatment group [$F(1, 37)=6.21$, $p=0.017$, $\eta^2=0.144$], delay [$F(1, 37)=51.55$, $p<0.001$, $\eta^2=0.58$] and time [$F(1, 37)=15.27$, $p<0.001$, $\eta^2=0.292$]. As can be seen from Fig. 3, the three-way interaction was attributable to poorer post-drink scores in the alcohol group for both immediate [$t(38)=2.36$, $p=0.024$] and delayed [$t(38)=3.87$, $p<0.001$] recall.

Correlations

To explore our hypothesis that retrospective memory impairments were contributing to the PM deficits observed in the alcohol group on the standard Virtual Week task, we correlated scores from regular, irregular and time-check tasks with delayed prose recall scores in the alcohol group, with an adjusted $\alpha=0.017$. The proportion correct for irregular tasks correlated with delayed prose recall in this group [$r=0.564$, $p=0.012$] but prose recall did not significantly correlate with regular and time-check tasks.

Discussion

Our study aimed firstly to assess the acute effects of a 0.6 g/kg dose of alcohol on PM. We found a significantly poorer performance following alcohol administration across all three types of PM tasks: regular, irregular and time-check tasks, in both time-based and event-based tasks in comparison to the placebo group. These results are consistent with prior research that has assessed the effect of acute alcohol on PM function using self-report measures. This is, however, the first study to assess the acute effects of alcohol on prospective remembering using a laboratory measure that simulates the PM tasks in everyday life and has clear implications for everyday function.

Consistent with the idea that retrospective memory deficits contribute to PM failure and in accordance with previous findings (e.g. Moulton et al. 2005), alcohol significantly impaired performance on the prose recall task, for both immediate and delayed recall. Furthermore, the

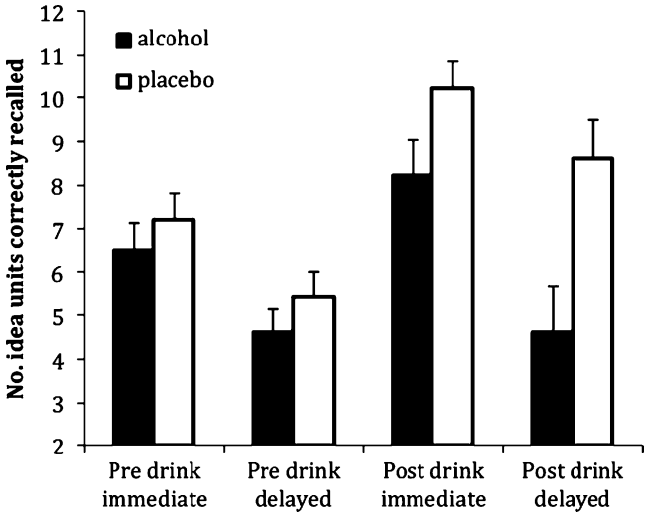

Fig. 3 Prose recall across delay, time point and treatment group (*bars* represent standard errors)

positive correlation between irregular PM tasks and delayed recall, which primarily taps episodic remembering, stresses the central role of episodic memory in prospectively remembering to carry out infrequent tasks. This correlation suggests that 31% of the variance between irregular PM tasks and episodic memory is shared. Alcohol had no impact on performance on the TOL, indicating intact executive planning capabilities and, in turn, suggesting that PM failure in this study was linked with episodic remembering rather than executive deficit. The findings of this study also suggest that retrospective memory failures are not sufficient to account for the impairment due to alcohol on the prospective memory tasks. Supporting this conclusion is the lack of a correlation between prose recall and the regular tasks and the generalised impairment due to alcohol observed across each type of task. Particularly noteworthy is the consistent impairment across regular and irregular tasks, given that the regular tasks arguably place heavier load on retrospective memory (Kliegel et al. 2008).

Our second aim was to investigate the role of episodic future thinking in PM. The results indicate that FES might play an important role in successful prospective remembering. The FES strategy did not help participants in the alcohol group. This suggests either that alcohol prevented participants from engaging in episodic future thinking, or that they engaged in this but it did not provide a subsequent mnemonic advantage. While, following strict statistical corrections, there was only a trend for the FES strategy relative to the no strategy condition to help participants in the placebo group on irregular event-based tasks, it is important to note that the exclusion of regular and time-check tasks in study 2 decreased the sensitivity of the Virtual Week task, with only two irregular event-based tasks available each 'day'. Future studies should explore the impact of simulation over a greater number of days on Virtual Week.

As predicted, in the placebo group, the FES strategy significantly helped performance on event-based tasks—which rely on cues in the environment, relative to time-based tasks—which depend on effortful monitoring. Our findings support the idea that PM performance is improved by associating an intention with the specific environment in which intention-completion is likely to take place. This is consistent with numerous studies reporting that implementation intentions facilitate PM performance (e.g. Cohen and Gollwitzer 2008; Gollwitzer 1999; McDaniel et al. 2008; Sheeran and Orbell 1999). These suggest that the linkage of an intended action to specific situational cues (by means of an implementation intention, i.e. an 'if…then' plan) allows automatic triggering of the intention when cues are encountered. It could be, then, that FES might be one of the mechanisms by which implementation intentions produce their positive effects. Similarly, Seifert and Patalano's (2002) predictive encoding model suggests that if an intention has been associated with a specific cue, the later presence of the cue in the environment automatically brings the intention to mind.

We suggest that simulating a future scenario allows one to pre-experience the visual–spatial contexts in which intention-completion will take place. In turn, entering the intention-completion environment causes the mentally pre-experienced visual–spatial contexts to reactivate and act as cues that prompt intention-completion. These findings are consistent with the constructive episodic simulation hypothesis (Schacter and Addis 2007), which predicts that memories for past events and thoughts for future events draw on similar information stored in episodic memory (Schacter and Addis 2007). Indeed, in order to imagine an effective future intention-completion scenario, one must successfully combine fragments from past memories to create a new, plausible scenario so as to ensure that entering the intention-completion environment will trigger those cues that lead to successful PM performance. The present data are consistent with the suggestion of Szpunar et al. (2009) that past and future thoughts both involve the reinstatement of familiar context from memory and, more specifically, that episodic future thinking invokes memory for known visual–spatial contexts (as evidence by indistinguishable activity of regions of posterior cortex when remembering and imagining a specific future episode in familiar contexts).

This is the first investigation of the role of FES in prospective remembering and, as such, it is of an exploratory nature. A limitation was that, due to testing time constraints within the peak effects of alcohol, only one FES 'day' of the adapted version of Virtual Week could be administered. Because regular tasks had to be excluded from the analysis,

only four irregular tasks were available to assess FES, which decreased the sensitivity of the task. Time constraints also did not preclude a more thorough investigation of the role of executive functioning.

In summary, this study showed that, acutely, a dose of alcohol corresponding to 4–5 units produces global impairments of PM. It would be important to conduct a similar study with alcohol abusers, as PM *abilities* are central to all forms of learning-based therapies that are routinely used in treatment (e.g. Heffernan et al. 2002) and we suggest that PM *failures* are a key aspect of relapse. Relapse can be seen as a failure to carry out an intention (i.e. of abstinence from alcohol use). As such, relapse may in part reflect a failure of prospective memory. To explore this, we are currently investigating prospective memory in alcohol-dependent patients undergoing treatment.

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