Global Impairment of Prospective Memory following Acute Alcohol

Julie R. Leitz [1], Celia J.A. Morgan [1], James A. Bisby [1],

Peter G. Rendell [2], H. Valerie Curran[1]

[1] *Clinical Psychopharmacology Unit, University College London*
[2] *School of Psychology, Australian Catholic University, Melbourne*

Corresponding author:
H. Valerie Curran
Clinical Psychopharmacology Unit
Research Department of Clinical, Health and Educational Psychology
University College London
Gower St.
LONDON
WC1E 6BT
v.curran@ucl.ac.uk

ABSTRACT

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. With this aim, the present study determined the acute effects of alcohol upon PM (i) using the ecologically valid Virtual Week task in its standard form with regular, irregular; event-based and time-based PM tasks; (ii) using an adapted version which enabled exploration of how future-

event simulation at encoding impacted upon subsequent PM. Forty healthy volunteers were administered 0.6g/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. 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 the alcohol group. These findings on an ecologically valid assessment of PM suggest that 4-5 units of alcohol will compromise PM abilities in everyday life.

INTRODUCTION

Memory impairment is a robust acute effect of the world's most popular drug, alcohol. Numerous studies have shown its effects range from mild deficit at low doses through to 'black-out' at high doses (for reviews see Curran & 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, Rogers, & Duka, 2005;

Weissenborn & 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 & 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, Della Sala, Logie, & Maylor, 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 (ie., "I must do something at 4pm"), but also of the content of the action (ie., "I must call the plumber at 4pm"; Cohen, West, & Craik, 2001; Brandimonte, McDaniel, & Einstein, 1996; McDaniel & Einstein, 1992). Prospective memory tasks also require an individual to recall the action at a designated future time without an 'instruction' to remember (Einstein & 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, Ramuschkat, & Martin, 2003; McDaniel, Howard, & Butler, 2008).

It is important to differentiate between *time*-based and *event*-based PM tasks (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; McDaniel & Einstein, 1992). Time-based tasks require an individual to carry out an action at a specific time (eg., making a phone call at 4pm), so that the required behaviour is reliant upon self-initiated mental activities (ie., clock checking). In event-based tasks, in contrast, the required behaviour is prompted by an external cue (eg., 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 (eg., taking medication

at 6pm every day), while irregular tasks are the occasional tasks of everyday life (e.g., returning a DVD on the way home, Rendell, Jensen, & Henry, 2007). Irregular tasks place a greater load on retrospective memory than regular tasks (Kliegel, Rendell and Altgassen, 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, Adams, Harrington, Fries-Dias, & Gipson, 1995). These report that excessive alcohol use by teenagers (Heffernan & Bartholomew, 2006) and chronic heavy alcohol use in adults (Heffernan, Moss, & Ling, 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., 2007).

The first aim of this study, therefore, was to directly assess the effects of two doses of alcohol on PM using an objective, ecologically valid measure of PM: the Virtual Week task (Rendell & Craik, 2000). This task was specifically chosen because it allows the investigation of the different types of PM tasks in daily life (regular, irregular; event-based, 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 0.6g/kg dose of alcohol because it would impair memory while leaving executive planning intact (Finn, Justus, Mazas, & Steinmetz, 1999; Townshend & Duka, 2002).

In an inspiring article, Atance and O'Neill (2001) have suggested that the planning component of prospective remembering might be a possible link between future-event simulation, or 'episodic future thinking' (Schacter & Addis, 2007), and PM. They identify future-event simulation as possibly especially important in the process of developing a mnemonic that will allow us to remember our intended action in the future. Further, in a recent review, Schacter, Addis and Buckner (2008) similarly ask whether

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 question by addressing the potential role of future-event simulation in prospective remembering.

Our hypothesis was that PM performance could be improved by associating an intention with the specific visuo-spatial context in which in which it would be carried out (eg., 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 we are likely to engage in the future. Following this line of thought, we suggest, as others have (see Atance & O'Neill, 2001; Schacter *et al.,* 2008) that future-event simulation might facilitate successful prospective remembering. More specifically, we predicted that PM performance would be improved by associating an intention with the specific visuo-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, (i) 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 (ii) a standard condition in which participants were not given any strategy at encoding. We predicted that future-event simulation would specifically aid prospective remembering on event-based tasks as opposed to time-based tasks. Indeed, as outlined earlier, while time-based tasks require the conscious monitoring of the environment for cues, in event-based tasks, intention retrieval is prompted by an external cue in the environment. Thus, we hypothesised that simulating the environment in which intention completion will take place would facilitate intention encoding and retrieval, leading to better prospective remembering on event-based tasks in comparison to time-based tasks in the placebo group.

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).

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)

Design

In a double-blind independent group design, males and females were randomly assigned to either the placebo or the alcohol condition ($n = 20$; 10 women in each group).

Alcohol administration

Alcohol was administered at a dose of 0.6 g/kg. Following Knowles and Duka's (2004) procedure, ninety percent ethanol was diluted with tonic water (Schweppes Ltd., Uxbridge, UK), equally divided into 10 x 50ml 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 x 50ml portions of tonic water and Tabasco sauce only. Participants consumed the ten beverages at 3 minute intervals in the presence of the experimenter. To maintain the level of alcohol over the entire testing period of 90 minutes, 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 50ml portions and administered at the times shown in Table 1, which pilot work had shown maintained steady BAC levels over the period of testing.

Procedure

On arrival at the laboratory, participants gave informed consent and completed the Alcohol Use Questionnaire (AUQ) and a mood rating scale (MRS). A baseline blood alcohol concentration (BAC) measure was taken to ensure that participants were sober and then they carried out the assessments detailed below in the order given in Figure 1.
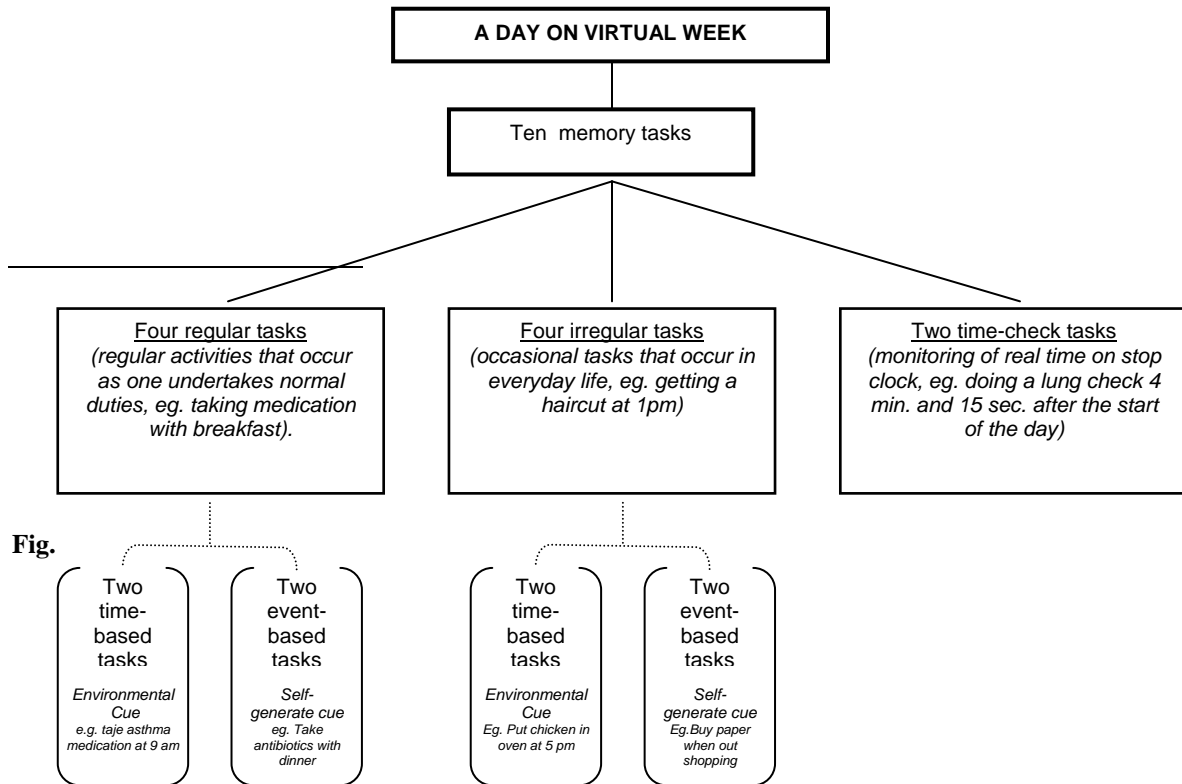
Table 2. *Procedure: tasks and measures performed with corresponding times (mins).*

Time (mins)	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 (± .22)
	Three days of the standard Virtual Week task
70	Top-up drink 1 (0.1 g/kg)
80	BAC 2 = 0.59 (± .21)
	Encoding phase of Remember Know task
90	Top-up drink 2 (0.1 g/kg)
	Tower of London
	Prose recall 2 immediate recall task
100	BAC 3 = 0.67 (± .21)
	Adapted Virtual Week: day 1
110	Top-up drink 3 (0.1 g/kg)
	Adapted Virtual Week: day 2
120	BAC 4 = 0.69 (± .21)
	Adapted Virtual Week: day 3
130	Recognition phase of Remember Know task
	Delayed recall tasks for prose recall 1 and 2
140	Guess on treatment
	Debriefing and payment

Assessments

Standard Virtual Week (Rendell & Craik, 2000)

Virtual Week is a computerised task 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 and allows the assessment of the different types of PM failures (Figure 1).. Each day includes (1) four regular tasks, which are tasks that occur during normal duties (two of which are time-based and two of which are event-based); (2) four irregular tasks, which simulate occasional tasks of everyday life (two of which are time-based and two of which are event-based); (3) two time-check tasks requiring the participant to break from the board-game and monitor real-time on a stop-clock to indicate when a specific time-period has passed.

A DAY ON VIRTUAL WEEK

Ten memory tasks

Four regular tasks
(regular activities that occur as one undertakes normal duties, eg. taking medication with breakfast).

Four irregular tasks
(occasional tasks that occur in everyday life, eg. getting a haircut at 1pm)

Two time-check tasks
(monitoring of real time on stop clock, eg. doing a lung check 4 min. and 15 sec. after the start of the day)

Fig.

Two time-based tasks

Environmental Cue e.g. taje asthma medication at 9 am

Two event-based tasks

Self-generate cue eg. Take antibiotics with dinner

Two time-based tasks

Environmental Cue Eg. Put chicken in oven at 5 pm

Two event-based tasks

Self-generate cue Eg.Buy paper when out shopping

1a. *Different types of prospective memory tasks included in each day of Virtual Week.*

PM task
e.g. "Drop in the dry-cleaning when you go shopping later today"

Standard Condition

No strategy given

Rehearsal Condition

Participants were instructed to repeat aloud "Drop in dry-cleaning when shopping" for ten seconds (timed by the examiner).

Simulation Condition

Participants were instructed to close their eyes and, for ten seconds (timed by the examiner), imagine that they are going shopping later that day and drop-in the dry cleaning.
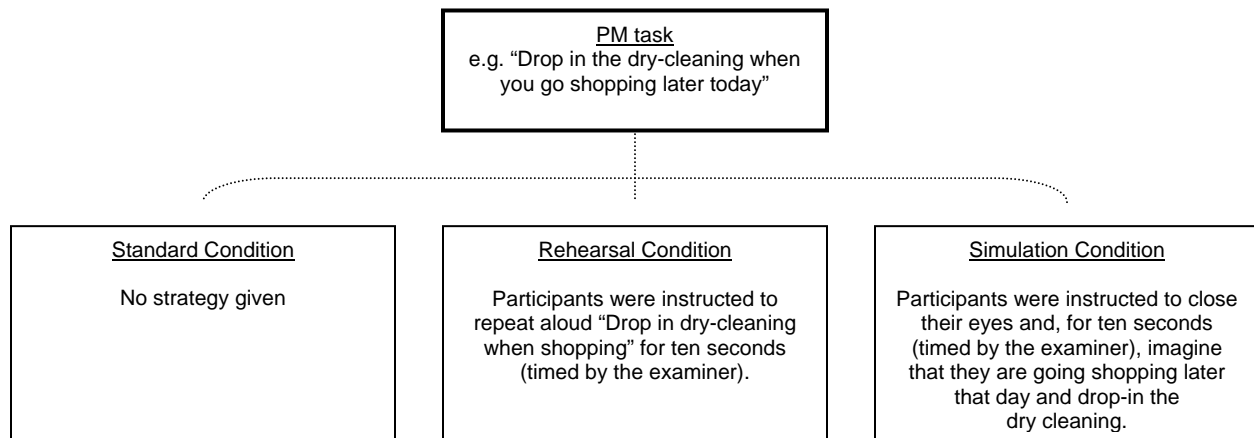
Fig. 1 b). *Standard condition, Rehearsal condition and Simulation condition of the adapted version of Virtual Week.*

Adapted Virtual Week: Future-event simulation in PM

Virtual Week was adapted so as to allow the investigation of the role of future-event simulation in prospective remembering. Participants were asked to complete three additional days of Virtual Week (see Figure 1 b). 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 ten seconds, or to simulate (Simulation condition) each of the intention-completion PM scenarios for ten seconds. 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 future-event simulation (see D'Argembeau & Van der Linden, 2004; D'Argembeau & Van der Linden, 2006; Szpunar & 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 & Zillmer, 2001; 2005)

The standard TOL was administered. The task, originally developed by Shallice (1982), taps higher-order problem solving and specifically executive planning abilities. The following TOL 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 seconds 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; initiation time plus execution time.

Prose recall (RBMT: Wilson, Cockburn, & Baddeley, 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.

Guess on treatment

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 & 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 & 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

The mean (± *SD*) blood alcohol concentrations (BAC) at 40, 80, 100 and 120 minutes after the end of alcohol consumption were 0.50 ± 0.22, 0.59 ± 0.21, 0.67 ± 0.21 and 0.69 (± .21) g/l respectively.

Guess on treatment

Chi square analysis of participants' guess on treatment showed a significant difference between correct / incorrect responses (χ^2 (1) = 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) = 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 (Figure 2)

A mixed 2 X 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, [$F(1, 38) = 11.22$, $p = .002$, $\eta^2 = .228$] and PM task [$F(1, 38) = 25.49$, $p < .001$, $\eta^2 = .401$] but no interaction.. As seen in Figure 2, 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 .017) revealed that the main effect of PM task was attributable to poorer performance on the irregular [$t(39) = 7.34$, $p < .001$, 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 [$t(39) = 5.46$, $p < .001$, $d = 1.08$]

tasks compared to the regular task, but no differences between the irregular and time-check tasks.

A 2 x 2 mixed ANOVA of time- versus event-based tasks yielded a significant main effect of Treatment [$F(1, 38) = 14.32$, $p < .001$, $\eta^2 = .274$], but no interaction, again reflecting poorer performance across both tasks following alcohol compared to placebo.
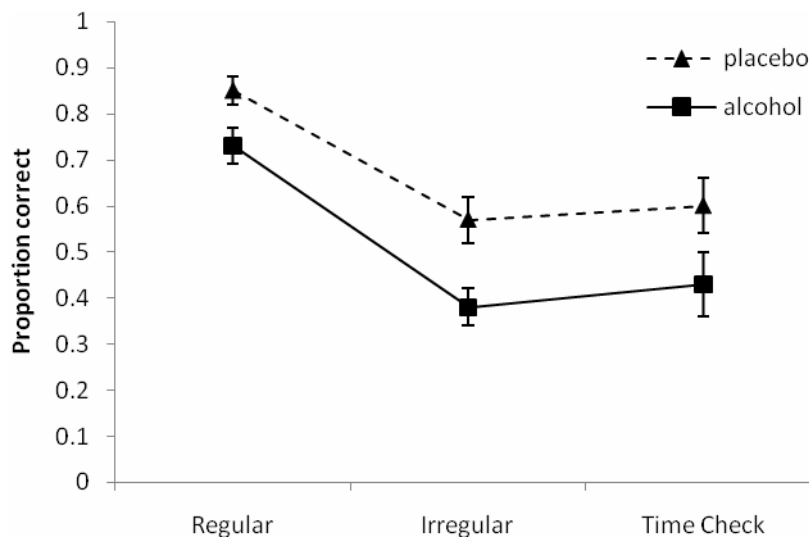

Fig. 2. *Proportion Correct on Standard Virtual Week-task by treatment group on Time-Check vs Irregular vs Regular (bars represent standard errors)*

Future-Event Simulation Virtual Week (Figure 3)

A mixed 2 x 2 x 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 3 way interaction between Treatment group, PM target and Strategy, [$F(2, 76) = 3.52$, $p = .034$, $\eta^2 = .085$]. There was also a significant main effect of Treatment group, [$F(1, 38) = 5.46$, $p = .025$, $\eta^2 = .126$] and a trend towards a main effect of Strategy [$F(2, 76) = 3.01$, $p = .055$, $\eta^2 = .073$].

To explore the 3-way interaction, paired samples t-tests (Bonferroni corrected – alpha was .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 [$t(19) = 2.52$, $p = .021$, $d = .68$, a moderate effect size], reflecting better performance for event-based tasks following the simulation strategy than time-based tasks [Figure 3 a) and b)].
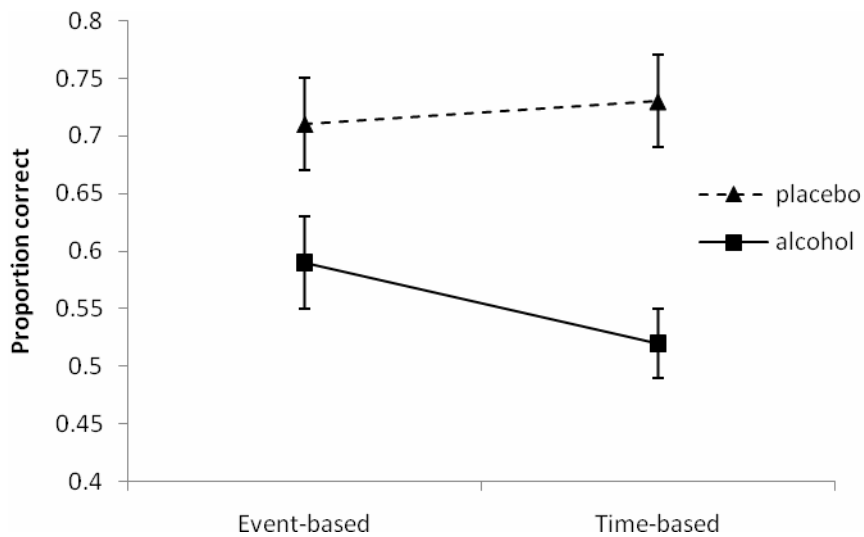

Fig. 3 a). *Group means for proportion of event and time-based tasks correct on the Adapted Virtual Week task(bars represent standard error).*
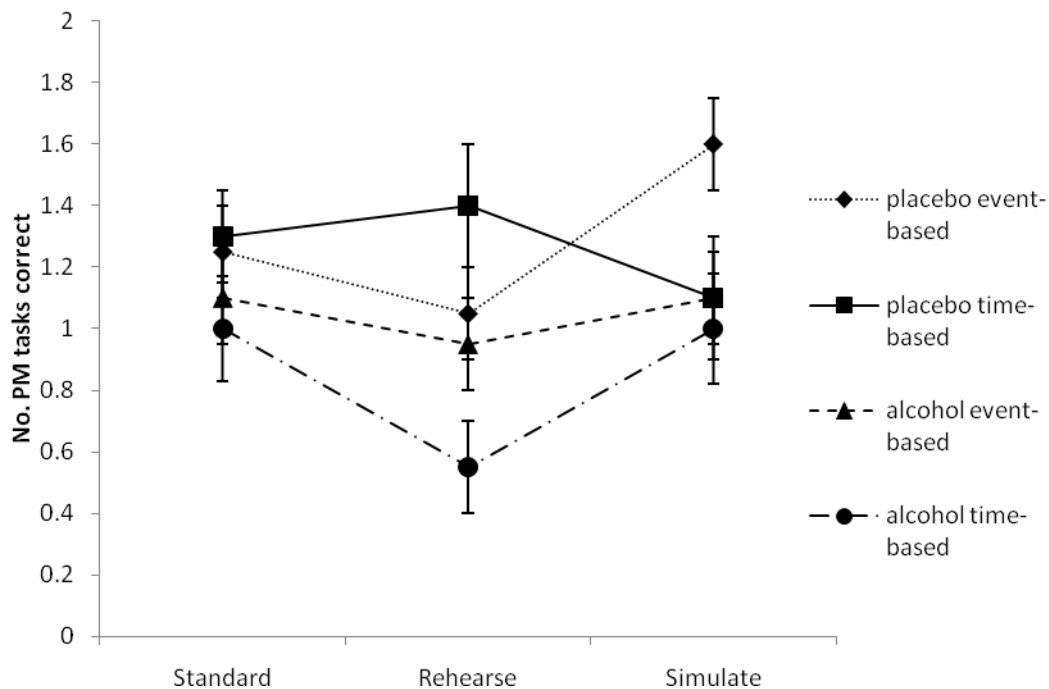
Fig. 3 b). Group means for number of correct PM tasks *on the Adapted Virtual Week task by encoding condition (bars represent standard errors).*

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 of imagery during future event simulation, 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 (Table 3)

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. *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)

Prose recall

A 2 x 2 x 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, $[F(1, 37) = 7.28, p = .01 , \eta^2 = 0.164]$. There was also a Time x Group interaction $[F(1, 37) = 6.03, p = .019, \eta^2 = 0.14]$ and main effects of Treatment group, $[F(1, 37) = 6.21, p = .017 , \eta^2 = 0.144]$, Delay $[F(1, 37) = 51.55, p < .001, \eta^2 = 0.58]$ and Time $[F(1, 37) = 15.27, p < .001, \eta^2 = 0.292]$. As can be seen from Figure 4, the three way interaction was attributable to poorer post-drink scores in the alcohol group for both immediate $[t(38) = 2.36, p = .024]$ and delayed $[t(38) = 3.87, p < .001]$ recall.
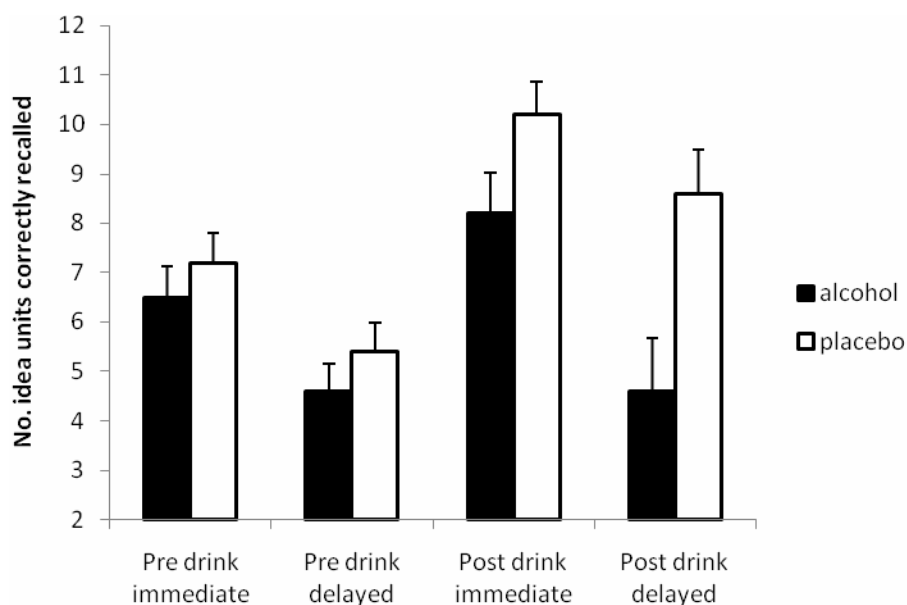

Fig. 4. *Prose recall across Delay, Time point and Treatment Group (bars represent standard errors).*

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 α = .017. The proportion correct for irregular tasks correlated with delayed prose recall in this group [r = .564, p = .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 an objective laboratory measure that allows the investigation of the different types of PM failure 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 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 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 future-event simulation might play an important role in successful prospective remembering. The future-event simulation 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 future-event simulation 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 future-event simulation 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 & Gollwitzer, 2008; Gollwitzer, 1999; McDaniel et al., 2008; Sheeran & Orbell, 1999). These suggest that the linkage of an intended action to specific situational cues (by means of an implementation intention, ie., an "if…then" plan) allows automatic triggering of the intention when cues are encountered. It could be, then, that future-event simulation might be one of the mechanisms by which implementation intentions produce their positive effects. Similarly, Seifert & 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.

It seems that simulating a future scenario allows us to pre-experience the visuo-spatial contexts in which intention completion will take place. In turn, entering the intention completion environment causes the mentally pre-experienced visuo-spatial contexts to reactivate and act as cues that prompt intention completion. These findings are consistent with the constructive episodic simulation hypothesis (Schacter & Addis, 2007), which predicts that memories for past events and thoughts for future events draw on similar information stored in episodic memory (Schacter & Addis, 2007). Indeed, in order to imagine an effective future intention-completion scenario, we 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.

This is the first investigation of the role of future-event simulation 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 future-event simulation "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 future-event simulation, 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 (eg. Heffernan, Moss, Ling, 2002) and we suggest that PM *failures* are a key aspect of relapse.

References:

Atance, C. M. & O'Neill, D. K. (2001). Episodic future thinking. *Trends in Cognitive Sciences, 5,* 533-539.

Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S. W., & Nathan, P. E. (2001). Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia, 39,* 376-389.

Brandimonte, G. O., McDaniel, M. A., & Einstein, G. O. (1996). *Prospective memory: Theory and applications*. Mahwah, NJ: Erlbaum.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum.

Cohen, A. L., & Gollwitzer, P. M. (2008). The cost of remembering to remember: Cognitive load and implementation intentions influence ongoing task performance. In M. Kliegel, M. A. McDaniel, & G. O. Einstein (Eds.), Prospective memory: Cognitive, neuroscience developmental, and applied perspectives (pp. 367-390). Mahwah, NJ: Erlbaum.

Cohen, A. L., West, R., & Craik, F. I. M. (2001). Modulation of the prospective and retrospective components of memory for intentions in younger and older adults. *Aging, Neuropsychology, and Cognition, 8,* 1-13.

Craik, F. I. M. (1983). On the transfer of information from temporary to permanent memory. *Philosophical Transactions of the Royal Society, Series B, 302,* 341-359.

Culbertson, W. C. & Zillmer, E. A. (2001). *Tower of London-Drexel University (TOLDX) technical manual*. (1st ed.) Tonawanda, N.Y: Multi-Health Systems.

Curran, H. V. & Weingartner, H. (2002). Psychopharmacology of human memory. In A. D. Baddeley, M. D. Kopelman, & B. A. Wilson (Eds.), *Handbook of memory disorders*. New York: Wiley, 123-141.

D'Argembeau, A. & Van der Linden, M. (2004). Phenomenal characteristics associated with projecting oneself back into the past and forward into the future: Influence of valence and temporal distance. *Consciousness and Cognition, 13,* 844-858.

D'Argembeau, A. & Van der Linden, M. (2006). Individual differences in the phenomenology of mental time travel: The effect of vivid visual imagery and emotion regulation strategies. *Consciousness and Cognition, 15,* 342-350.

Einstein, G. O., & McDaniel, M. A. (2005). Prospective memory: Multiple retrieval processes. *Current Directions in Psychological Science, 14*, 286–290.

Einstein, G. O., McDaniel, M. A., Richardson, S. L., Guynn, M. J., & Cunfer, J. R. (1995). Aging and prospective memory: examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21,* 996-1007.

Ewing, J. A. (1984). Detecting alcoholism. The CAGE questionnaire. *JAMA: The Journal of the American Medical Association, 252,* 1905-1907.

Finn, P. R., Justus, A., Mazas, C., & Steinmetz, J. E. (1999). Working memory, executive processes and the effects of alcohol on Go/No-Go learning: Testing a model of behavioral regulation and impulsivity. *Psychopharmacology, 146,* 465-472.

George, S., Rogers, R., & Duka, T. (2005). The acute effect of alcohol on decision making in social drinkers. *Psychopharmacology, 182,* 160-169.

Gollwitzer, P. M. (1999). Implementation intentions: strong effects of simple plans. *American Psychologist, 54,* 493-503.

Hannon, R., Adams, P., Harrington, S., Fries-Dias, C., & Gipson, M. T. (1995). Effects of brain injury and age on prospective memory self-rating and performance. *Rehabilitation Psychology Winter, 40,* 289-298.

Heffernan, T. M. & Bartholomew, J. (2006). Does excessive alcohol use in teenagers affect their everyday prospective memory? *Journal of Adolescent Health, 39,* 138-140.

Heffernan, T. M., Moss, M., & Ling, J. (2002). Subjective ratings of prospective memory deficits in chronic heavy alcohol users. *Alcohol and Alcoholism, 37,* 269-271.

Kliegel, M., Ramuschkat, G., & Martin, M. (2003). Executive functions and prospective memory performance in old age: an analysis of event-based and time-based prospective memory. *Zeitschrift für Gerontologie und Geriatrie, 36,* 35-41.

Kliegel, M., Rendell, P. G., & Altgassen, M. (2008). The added value of an applied perspective in cognitive gerontology. In S. M. Hofer & D. F. Alwin (Eds.), *Handbook of cognitive aging: Interdisciplinary perspectives* (pp. 587-613). Thousand Oaks, CA: Sage.

Knowles, S. K. Z. & Duka, T. (2004). Does alcohol affect memory for emotional and non-emotional experiences in different ways? *Behavioural Pharmacology, 15,* 111-121.

Kurtz, M.M., Moberg, P.J., Mozley, L.H. (2001) Effectiveness of an attention- and memory-training program on neuropsychological deficits in schizophrenia, *Neurorehabil. Neural Repai*r, *15,* 75–80.

Leckliter, I. N. & Matarazzo, J. D. (1989). The influence of age, education, IQ, gender, and alcohol abuse on Hastead-Reitan neuropsychology test battery performance. *Journal of Abnormal Psychology, 45,* 484-512.

Ling, J., Heffernan, T. M., Buchanan, T., Rodgers, J., Scholey, A. B., & Parrott, A. C. (2003). Effects of alcohol on subjective ratings of prospective and everyday memory deficits. *Alcoholism: Clinical and Experimental Research, 27,* 970-974.

Lockhart, RS. (2000). Methods of memory research. In E. Tulving & FIM Craik (Eds.), *The Oxford Handbook of Memory* (45-57). New Tork: Oxford University Press.

Mantya, T. (2003). Assessing absentmindedness: Prospective memory complaint and impairment in middle-aged adults. *Memory and Cognition, 31,* 15-25.

McDaniel, M. A. & Einstein, G. O. (1992). Aging and prospective memory: Basic findings and practical applications. *Advances in Learning and Behavioral Disabilities, 7,* 87-105.

McDaniel, M. A., Howard, D. C., & Butler, K. M. (2008). Implementation intentions facilitate prospective memory under high attention demands. *Memory and Cognition, 36,* 716-724.

Mehrabian, A. & Russell, J. A. (1978). A questionnaire measure of habitual alcohol use. *Psychological Reports, 43,* 803-806.

Moulton, P. L., Petros, T. V., Apostal, K. J., Park, R. V. 2nd, Ronning, E. A., King, B. M., & Penland, J. G. (2005). Alcohol induced impairment and enhancement of memory: A test of the interference theory. *Physiology and Behvavior, 85,* 240-245.

Rendell, P. G. & Craik, F. I. M. (2000). Virtual week and actual week: Age-related differences in prospective memory. *Applied Cognitive Psychology, 14,* 43-62.

Rendell, P. G., Jensen, F., & Henry, J. D. (2007). Prospective memory in multiple sclerosis. *Journal of the International Neuropsychological Society, 13,* 410-416.

Schacter, DL., Addis, DR. (2007). The cognitive neuroscience of constructive memory: remembering the past and imagining the future. *Phil. Trans. R. Soc. B., 362*, 773-786.

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2008). Episodic simulation of future events - Concepts, data, and applications. *Year in Cognitive Neuroscience 2008, 1124,* 39-60.

Seifert, C. L. & Patalano, A. L. (2002). Opportunism in memory: Preparing for chance encounters. *Current Directions in Psychological Science, 10,* 198-201.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London*, B 298, 199-209.

Sheeran, P., & Orbell, S. (1999). Augmenting the theory of planned behavior: Roles for anticipated regret and descriptive norms. Journal of Applied Social Psychology, 29, 2107-2142.

Smith, G., Della Sala, S., Logie, R. H., & Maylor, E. A. (2000). Prospective and retrospective memory in normal ageing and dementia: A questionnaire study. *Memory, 8,* 311-321.

Soderlund, H., Grady, C. L., Easdon, C., & Tulving, E. (2007). Acute effects of alcohol on neural correlates of episodic memory encoding. *NeuroImage, 35,* 928-939.

Szpunar, KK., McDermott, KB. (2007). Episodic future thought and its relation to remembering: evidence from ratings of subjective experience. *Consciousness & Cognition, 17,* 330-334.

Townshend, J. M. & Duka, T. (2002). Patterns of alcohol drinking in a populations of young social drinkers: A comparison of questionnaire and diary measures. *Alcohol and Alcoholism, 37,* 187-192.

Tulving, E. (1983). *Elements of episodic memory.* Oxford: Clarendon Press.

Tulving, E. (2005). Episodic memory and autonoesis: Uniquely human? In H.S.Terrace & J. Metcalfe (Eds.), *The missing link in cognition: Origins of self-reflective consciousness* (pp. 3-36). New York: Oxford University Press.

Weissenborn, R. & Duka, T. (2003). Acute alcohol effects on cognitive function in social drinkers: Their relationship to drinking habits. *Psychopharmacology, 165,* 306-312.

White, A. M. (2003). What happened? Alcohol, memory blackouts, and the brain. *Alcohol Research and Health, 27,* 186-196.

Wilson, A., Cockburn, J., & Baddeley, A. D. (1985). *The Rivermead Behavioural Memory Test*. Reading, UK: Thames Valley Text.