The effects of binge drinking upon young adults' prospective memory and related executive function

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ABSTRACT

Binge drinking is highly prevalent among young adults. A wide field of research has shown that the prefrontal cortex of the brain is vulnerable to the neurotoxic effects of alcohol, causing deficits prospective memory and executive functions. No previous research has explored the adverse effects of binge drinking on prospective memory related executive functioning. The first aim of the current study was to examine whether binge drinking in young adults has adverse effects on prospective memory. The second was to determine whether a binge drinker who suffers from an impaired prospective memory has associated deficits in their executive functioning. 44 participants were assessed using an objective measure of prospective memory (Virtual Reality Prospective Memory task) and an objective measure of executive function (Reverse Digit Span task). A between groups design was used; consisting of 'binge drinkers' and 'non-binge drinkers'. Two predictions were made, the first was that binge drinkers would remember significantly fewer prospective memory items on the VRPM task, the second prediction was that binge drinkers who had an impaired prospective memory would recall significantly fewer digits on the RDS task. After controlling for age, years spent drinking, last alcohol use, mood and recreational drug use. Binge drinkers remembered significantly fewer prospective memory items on the VRPM task and recalled significantly fewer items on the RDS task than non-binge drinkers. Further analysis indicated that executive functioning underpins PM. The results of the study suggest that binge drinking in young adults causes impairments in prospective memory and related executive functions.

KEY WORDS	BINGE DRINKING	PROSPECTIVE MEMORY	EXECUTIVE FUNCTION	VIRTUAL REALITY	REVERSE DIGIT SPAN

INTRODUCTION

Alcohol

Alcohol is one of the most widely used drugs in the world and has been shown to have a complicated role within human health and society. There are some positive benefits of alcohol. At low and moderate drinking levels alcohol can be associated with lower risks of heart disease, diabetes, and preventing strokes (Karlamangla et al., 2008). However, excessive alcohol consumption is responsible for enormous disruption in people's social and physical well-being (Mukamal and Rimm, 2008). Alcohol is now the third leading risk factor to health and according to the World Health Organisation (2011) the harmful use of alcohol worldwide results in the death of 2.5 million people annually. In 2006/07 there were 57,142 NHS admissions in England, with the primary diagnosis specifically related to alcohol. It should be noted that this number has increased by 50% since 1995/96 (Royal Collage of Physicians, 2009).

An episode of excessive alcohol intake over a short period of time is recognised as binge drinking (Craigs, Bewick, Gill, O'May, and Radley, 2011). Binge drinking is generally defined as the consumption of large quantities of alcohol in at least one session per week, equating to females consuming 48g ethanol (6 units at 8g per unit) on at least a single occasion and a male consuming at least 64g ethanol (8 units) on a single occasion or more (see e.g. Craigs et al., 2011; Office for National Statistics, 2004). It is this definition of binge drinking that will be used in the present research study.

Consuming such large amounts of alcohol in this way has shown to be most prevalent with young adults and university students (Heather et al., 2011), and according to Courtney and Polich (2009) young adults aged 18-25 years, evinced the highest rate of binge drinking episodes in the year 2001. The Institute of Alcohol Studies (IAS) (2007) found that binge drinking in adolescence and young adulthood is associated with increased risk of social and health adversity.

Social consequences

Hazardous consequences of binge drinking arise from the disabling effects of consuming an excessive amount of alcohol over a short period of time. The prevalence of violent behaviour is substantially higher among binge drinkers than non-binge drinkers. According to the IAS (2007) young binge drinkers are three times more likely to report committing an offence than those who drink but do not get drunk. In addition, binge drinking has been found to increase the likely hood of unwanted or unsafe sexual activity of young adults. Previous research suggests that after binge drinking one in seven 16-24 year olds have had unprotected sex, one in five have had sex they later regretted and one in ten have been unable to remember if they had sex the night before (IAS, 2007). Research by Hutton, McCaul, Santora and Erbelding (2008) showed that women who engaged in binge drinking have higher rates of risky sexual behaviour and higher rates of sexually transmitted diseases (STDs). Previous research has also demonstrated further risk factors relating to the effects of binge drinking on young adult's mood and behaviour. A study by Engineer, Phillips, Thompson and Nicholls (2003) explored the social context of binge drinking among young adults aged between 18–24 years. The research consisted of group discussions with young adults who had regular

experience of binge drinking. Subjects reported feeling more inclined to act on impulse and think less about the consequences of their actions when engaging in binge drinking activities, as well as feeling more likely to loose their tempers. Taken together, previous research demonstrates a significant association between binge drinking and co-occurring risky behaviours.

Health consequences

Binge drinking poses a serious danger to health for the individual and alcohol in general has been shown to be causally related to more than 60 different medical conditions (Room, Babor, Rehm, 2005). The nature and severity of problems caused by binge drinking depends on how frequently the binge drinking occurs and over how long a period it is maintained. Such adverse long term health effects specifically associated with binge drinking include liver disease, pancreatic disease, heart disease and strokes (Naimi, Brewer, Mokdad, Denny, Serdula and Marks 2003). Physical health can also be harmed when engaging in binge drinking sessions and at the time of intoxication there becomes a higher risk of heart irregularities, respiratory or circulatory failure and even the risk of inhaling vomit if unconscious, which could lead to death. In addition, people who binge drink are more vulnerable of developing psychological problems such as anxiety and depression. A study by Hoel, Eriksen, Briedablik and Meland (2004) revealed that depressive complaints and psychosomatic problems increased with increasing frequency of intoxication in teenagers. In some extreme cases (with 30 units or more of alcohol consumed) it has been found that hazardous drinking can even lead to psychosis, a severe mental illness.

Cognitive Functioning

Research suggests that people who binge drink run the risk of developing serious and persistent changes in their brains (National Institute of Alcohol Abuse And Alcoholism (NIAAA) 2004). According to Duka and Scaife (2009) there have been studies that have examined the effects of heavy binge drinking in university students and found alcohol-related brain structural and functional abnormalities. An area of the brain that has shown to be particularly vulnerable to the neurotoxic effects of alcohol is the prefrontal cortex (PFC). (Duka and Scaife, 2009). The PFC plays a central role in the control of cognition and behaviour (Wagner, Maril, Bjork, Schater, 2001) and as a result, is responsible for cognitive processes such as memory and executive functions. Executive functions facilitate people to engage in thoughtful and goal driven activities and include important behaviours such as planning, organising, problem solving, decision making and working memory (Blume and Marlatt, 2009). According to Courtney and Polich (2009) neuroimaging studies have demonstrated that binge drinkers compared to non-binge drinkers have been found to have smaller PFC volumes resulting from frontal white matter loss. It was assumed that the smaller PFC volume of the binge drinkers was associated with an impaired executive function and lower working memory scores than those of non-binge drinkers. Similarly, research by Garcia-Morena, Exposito, Sanhueza and Angulo (2008) found evidence to suggest that damage to the PFC by hazardous drinking also impaired executive functioning. Garcia-Morena et al., (2008) divided subjects into three groups; abstainers, subjects with moderate consumption of four or more alcoholic drinks on a single occasion and subjects with abusive consumptions of five or more drinks on one occasion. The tasks employed in the study included the digit span

task, corsi blocks task and stroop task, each of which depend on correct PFC functioning. The findings of this study showed that the subjects with moderate or an abusive pattern of alcohol consumption showed poorer performance in the tasks related to the dorsolateral prefrontal cortex functioning. A study by Parada, Corral, Mota, Crego, Holguin and Cadaveira (2011) showed that young adults (18-20 years) who engaged in binge drinking sessions were found to perform more poorly on tasks that require executive skills which depended on the functioning of the dorsolateral prefrontal cortex, than the non-binge drinking controls.

Research suggests that the PFC is also responsible for the control of prospective memory (PM) (Blume and Marlatt, 2009). PM is an important aspect of day-to-day memory function and is the cognitive ability to remember to carry out some activity at a future point in time (Heffernan, Clark, Bartholomew, Ling and Stephens, 2010). Theoretically, PM is thought to be composed of successive phases of (1) making and encoding future plans, (2) holding plans for a while, and (3) retrieving and executing the plan in association with the encoded context (Okuda et al., 1998). PM tasks are highly relevant to everyday life. Examples of a PM task would be remembering to take medication at a specific time each day or remembering to meet a friend at a pre-arranged time and place. A study by Okuda et al., (1998) presented subjects with tasks which reflected perspective memory for example holding an intention to perform a prospective action (tapping with the left hand) at the same time as performing a routine task (word repetition) and then remembering the intention (tapping with the left hand) in response to an appropriate event (appearance of a target item) Okuda et al., (1998). In the control task, the subjects were also required to engage in word repetition and holding the targets in mind, but they were not required to pay attention to the appearance of the targets or perform the prospective action. While subjects performed the PM tasks they underwent a PET scan (neuroimaging technique), which measured their cerebral blood flow (rCBF). Several localised brain activations were found in the brain in relation to the PM tasks; activations were identified in the right dorsal lateral and ventral lateral prefrontal cortices. In addition, observing the subjects rCBF during the PM task and the control task enabled the researchers to survey the areas associated with several important aspects on mental processes for PM, such as holding an intention or controlling attention. These findings provide further evidence that PM relies heavily on the PFC of the brain.

Given that the PFC becomes damaged by binge drinking and causes impairments in executive functioning, it is possible that a damaged PFC will have detrimental effects on PM. In addition, Paraskeraides, Morgan, Leitz, Bisby, Rendell and Curran (2010) suggest that executive functions can impact on PM performance and according to previous research, executive functioning is involved in the prospective component of PM, the formation and maintenance of future goals and plans (Mullan, Wong, Allom and Pack, 2011;Mahy and Moses, 2011). It could be expected that if executive functioning is impaired from binge drinking activities, then it is likely PM will be negatively affected as well. Kliegel, Jager, Altgassen, Shum (2008) state that research (Heffernan, Ling and Bartholomew, 2004) has demonstrated that PM deficits in chronic alcohol users are accompanied by impairments in every day executive functioning, providing further evidence that executive functioning is a precursor for PM.

There are only two studies to date that have explored the chronic effects of binge drinking on prospective memory. The first study by Heffernan, Clark, Bartholomew, Ling and Stephens (2010) explored whether teenage binge drinking has adverse effects upon PM. A Prospective Remembering Video Procedure (PRVP) was used as an objective measure of PM. The procedure involved a short video clip comprising footage of a shopping high street. Binge and non-binge drinking teenagers were required to remember particular actions/items associated with specific locations on the video. For example, 'when you see a woman sitting on a bench', 'Ask her the time' and 'when you reach Halifax', 'check if your loan has cleared'. It was found that binge drinkers recalled significantly fewer location action/items than non-binge drinkers which indicated that poorer PM performance was associated with binge drinking. The study also observed the effects of binge drinking upon self-reported everyday PM providing subjects with a Prospective and Retrospective Memory Questionnaire (PRMQ). It was found that binge drinkers and non-binge drinkers did not differ in the frequency of self reported PM lapses using the PRMQ (Heffernan et al., 2010). The second study by Heffernan and O'Neill (2012) also investigated whether binge drinking in young adults adversely affects PM. The study employed a self report memory measure (PRMQ) to explore PM memory lapses between the binge and non-binge drinking young adults, and an objective measure of PM was also obtained through using the Cambridge Prospective Memory Test (CAMPROMPT). The CAMPROMPT included three time-based PM tasks (e.g. 'Return a set of keys to the researcher when 7 minutes are remaining on the clock') and three event-based PM tasks (e.g. 'When a cue word is encountered during the filler task, remember to return a book to the researcher'). Results showed no significant difference between the binge and non-binge drinkers for self reported PM lapses, consistent with earlier research by Heffernan et al., (2010). However, binge drinkers were found to be impaired on the time-based PM tasks but not the event-based PM tasks. The finding that binge drinking has negative affects on PM in both studies is important. However, there are several limitations that should be addressed concerning the objective measures of PM used in both Heffernan et al., (2010) and Heffernan and O'Neill (2012). The Prospective Remembering Video Procedure (PRVP) used in Heffernan et al., (2010) is rather linear, whereby the participant has no choice but to be transported down the high street and there is no control for emersion or movement. There are no additional influences during the task such as distracters or unexpected delays that would be apparent in the real world. The PRVP therefore lacks ecological validity (Heffernan et al., 2010). The Cambridge Prospective Memory Test (CAMPROMPT) is a useful standardised task. Although similar to the PRVP it is short of real world PM tasks that would best reflect difficulties experienced by binge drinkers in their daily lives (Heffernan and O'Neill, 2012). The study by Heffernan et al., (2010) and Heffernan and O'Neill (2012) have produced interesting findings, demonstrating that binge drinkers show more deficits in their PM compared to non-binge drinkers using objective PM tasks. However, there needs to be further verification of the findings using different methodology to provide convergent evidence.

Rationale

The first aim of the current study is to investigate whether binge drinking has detrimental effects on a young adult's prospective memory (PM). The Virtual Reality Prospective Memory task (VRPM) will be used as an objective measure of PM. The VRPM task has been developed by researchers from the University of East London

and is a standardised task originally used to measure everyday memory, including prospective memory (Jansari, Agnew, Akessan and Murphy, 2004). For the purpose of the current project the VRPM task has been modified with PM items (for more detail see method section.) The advantage of the VRPM task as a measure of PM is that it is akin to the real world (Bohil, Alicea and Biocca, 2011) and involves navigating around a computerised office environment. The VRPM measure is semi-immersive as the participant can move themselves around the environment, enhancing the ecological validity of the task. Another advantage of the VRPM task is that the environment stays the same for each participant, which controls for extraneous factors coming into play. For example, if you were in the real world there could be distractions and unexpected delays e.g. bumping into a friend. If binge drinking does damage the PFC and as a result impairs PM in young adults as previous research suggests, then it can be predicted that binge drinkers will perform more poorly on the VRPM task accordingly, in comparison with non-binge drinking controls. In addition, since previous research shows that binge drinking has detrimental effects on the PFC, a region found to be responsible for PM and executive functioning, the second aim of the present study is to explore whether a binge drinker who shows impairments in their PM will have associated impairments in their executive functioning. An objective measure of executive functioning will be Reverse Digit Span task previously used in Parada et al., (2011) (for more detail about the RDS task see method). It could be predicted that binge drinkers who perform more poorly on the VRPM task (remembering fewer PM items) will achieve lower scores on the RDS task (recalling fewer digits) compared with non-binge drinkers. Other drug use will be controlled for using the Recreational Drug Use Questionnaire (RDUQ), while the Hospital Anxiety and Depression Scale (HADS) will also be implemented to control for mood in participants and if necessary, will be co-varied for in the statistical analysis, as these variables are known to affect memory performance. Previous research suggests that women are more vulnerable to the neurotoxicity of alcohol than men (Duka and Scaife, 2009), therefore only females will be used in this study to control for gender differences. In addition, since the project is focused on young adults, the age range for volunteers willing to take part in the study will be restricted to 18–25 years of age. There will be two groups of participants involved in this research based on their alcohol consumption in units per drinking session - ‘binge drinkers’ or ‘non-binge drinkers’. The two groups will be discussed in more detail in the method section of the report, along with a more detailed description of the measures used. All participants would not have consumed alcohol for at least 48 hours prior to taking part in the study, as according to the IAS (2007), a single episode of binge drinking has been shown to cause significant impairment of memory during a hangover in healthy subjects.

METHOD

Design

The present research utilised a between subjects group design, with alcohol group: binge drinkers vs. non-binge drinkers as the independent factor. (The operational definition of binge drinking used in this study was defined as: the consumption of large quantities of alcohol in at least one session per week. Equating in females to consuming 48g ethanol (6 units at 8g per unit) on at least a single occasion, this is

consistent with Craigs et al., (2011)). Scores on the virtual reality prospective memory task (VRPM) and reverse digit span (RDS) task were the dependant factors. The covariates used in the current study were, the age of the participant, years they had spent drinking, their last alcohol use in hours, their mood (anxiety and depression) and their recreational drug use (i.e. smoking, cannabis and ecstasy) and were measured and analysed between the groups. Gender was controlled for and therefore only females took part in the study since they are said to be more vulnerable to the neurotoxic affects of alcohol than males (Courtney and Polich, 2009). The order and presentation of the VRPM and RDS tasks and questionnaires remained consistent across participants to control for order effects.

Participants

All participants were recruited through opportunity sampling. The 44 volunteers consisted of fellow psychology students, family and friends who were aged between 18-25 years and met the required criteria for this research. Psychology students who volunteered to take part were eligible to receive one research point for taking part, issued through the SONA systems experiment management software.

24 females were categorized as ‘binge drinkers’ (which equates to consuming more than 6 units of alcohol in a least one session per week for a female). The average age for the binge drinkers was 19.70 years (SD=1.39), who drank on an average of 2.00 binge sessions per week (SD=1.25) and consumed on average 16.23 units per session (SD=7.35). On average the binge drinkers had spent 4.54 years drinking (SD=2.10) and had not had a drink for an average of 81.00 hours (SD=42.35). The other 20 females were categorized as ‘non-binge drinkers’. The average age for the non-binge drinkers was 20.70 years (SD=1.75), who drank on an average of 2.20 sessions per week (SD=0.89) and consumed on average 4.22 units per session (SD=2.56). On average the non-binge drinkers has spent 3.95 years drinking (SD=1.57) and had not had a drink for an average of 65.30 hours (SD=25.49). All participants had not consumed alcohol for at least 48 hours. Only a couple of participants reported previously using other drugs (e.g. cannabis or ecstasy). However this was such a small amount it was incalculable.

Materials

Virtual Reality Prospective Memory task (VRPM)

An objective measure of prospective memory was obtained through employing the Virtual Reality Prospective Memory Task (VRPM) originally designed by researchers at the University of East London (Jansari, Agnew, Akessan and Murphy, 2004). For the purpose of the present study the VRPM task has been modified with PM items. The VRPM task is a computerised task with a virtual office like environment displayed on the screen. The PM component is achieved by providing participants with a list of 12 PM items that have to be remembered while they navigate through the virtual office environment. For example, ‘put the coffee maker on the table at the front of the room’ and ‘put the post to be sent document in the completed tray’ (for a full list of the PM items see appendix 1). Participants can gain access to two separate rooms in the office building, completing numerous tasks in each. It was ensured that the participant fully understood the instructions before proceeding with

the task and the researcher monitored the participants throughout the VRPM task to ensure that they followed the correct procedure. The greater the number of PM items remembered and completed during the task the more proficient PM. (See appendix 1 for a copy of the VRPM).

Executive Function Reverse Digit Span task

An objective measure of executive functioning was taken by administering the Reverse Digit Span task (RDS). Participants are verbally presented with lists of digits at a rate of 1 item per second, participants are then asked to recall back the series of digits in reverse order. For example if the researcher reads aloud '1, 2, 3' the participant should recall back in reverse order '3, 2, 1' (see appendix 2 for a full copy of the digits presented to the participants). It should be noted that participants cannot see the digits nor take notes. There are 5 levels each with 3 trials, and each level increases by one digit. The first level begins with 3 digits in each trial and the final level has 7 digits in each trial. Participants progress to the next level if two or more trials on each level are completed correctly. Scoring on the RDS task was as such that the more levels that were completed by the participant the more proficient executive functioning they had. (For a full example of the RDS task see appendix 2).

Hospital Anxiety and Depression Scale (HADS)

A Hospital Anxiety and Depression Scale (HADS: Snaith and Zigmund, 1994) was used to measure participant's levels of anxiety and depression. The questionnaire was originally developed to detect the presence of any acute mood disorders, depression or anxiety in hospital out patients; however the HADS can be used in non-clinical samples (Crawford, Henry, Crombie and Taylor, 2001; White, Leach, Sims, Atkinson, and Cottrell, 1999). The HADS is a 14-item self-report, of which seven items are related to the loss of interest and diminished pleasure aspects of depression, and seven items related to generalised anxiety symptoms. Participants are asked to respond to each statement closest to how they have been feeling in the last week. An example of an item would read 'I feel cheerful' (depression) or 'I feel restless as if I have to be on the move (anxiety). The HADS employs a four choice response format (0-3), with higher scores corresponding to higher levels of anxiety and depression with a maximum score of 21 for each sub-scale. (For a full example of the HADS, see appendix 3).

Drug-Use Questionnaire

Recreational drug and alcohol use were assessed through the Recreational Drug Use Questionnaire (RDUQ). The RDUQ (previously used by Heffernan et al., (2010) and Parrott, Buchanan, Scholey, Heffernan, Ling and Rodgers (2002)) measured participants weekly binge drinking intake of alcohol in units per session. Examples of types of drinks that might be consumed in a typical week were given as guidance (e.g. ½ pint beer, 3 standard glassed of wine, 6 double vodkas etc.) and it is also explained that a 'session' is the equivalent of a single night out. It should be noted that the researcher calculated the number of units consumed in each session by the participants after the whole procedure had been completed, in order to eliminate any confusion the participants might have had when calculating the units they consumed in each session. Participants were asked to report how long (in years) they had been drinking alcohol and when they had their last drink (in hours.) In order to control for other drug-use, the questionnaire also gives details on cigarette smoking (cigarettes

smoked per week, years spent smoking and time spent with smokers), ecstasy use (pills) and any other recreational drug use. (For a full example of the RDUQ, see appendix 4).

Procedure

The procedure applied to the present study had been approved by the under graduate ethics committee at Northumbria University (see appendix 5 for ethics form). Test settings involved a quiet and undisturbed environment with a computer for each participant to complete the VRPM and RDS tasks, HADS and RDUQ. Participant information forms were given first, which provided an overview of the study and presented the necessary information in case the participant wished to later withdraw their data from the study, up to the point of analysis (see appendix 6 for an example of participant information sheet). It should be noted that at this point the participants did not know that the research focused on binge drinking per say. Rather, participants were informed the research was exploring alcohol use. Following this if the participants wished to continue and participate in the study, they were given a consent form to read and sign (see appendix 7). Once consent had been given, the researcher gave a brief example of how to navigate around the virtual office using several keys on the computer key board to make sure the participants fully understood the task. Participants read the list of instructions and tasks to remember for the VRPM task and were given the chance to ask the researcher any questions before the video commenced. Once it was ensured that the participants fully understood the procedure the VRPM task was switched on and the task completed. While participants were completing the VRPM task the researcher made note of whether the participant successfully completed or failed to complete each task respectively. Once the VRPM procedure had been completed, participants were asked to complete the executive function RDS task. Series of digits were verbally presented to the participants, who then attempted to recall them back in reverse order. The level that the participant achieved on the RDS task was recorded. Finally, the researcher administered the RDUQ followed by the HADS to the participants. Participants were informed that there was no time limit to complete the questionnaires and the researcher was on hand at all times to answer any questions that they may have regarding the completion of the questionnaires. Following the completion of both questionnaires, participants were given a debriefing sheet (which explained the true nature of the study). The debrief sheet (see appendix 8) included all relevant information needed if participants later wished to withdraw their data from the current study. In the circumstance that participants had requested feedback on the overall research findings (after completion of the data analysis) via their university email address, they would receive an electronic copy of the ‘End of Project Participation Feedback Form’ (see appendix 9).

RESULTS

All data from the study was analysed using SPSS version 19. Descriptive statistics (compromising of means and standard deviations) were obtained from the non-memory measures, and then from the memory measures following a series of statistical tests. In addition, inferential statistics were applied to analyse the between groups main effect on the memory measures and non-memory measures.

Table 1

Means and standard deviations for each group 'binge drinkers' (BD) and 'non-binge drinkers' (NBD) on all non-memory measures including, age, years spent drinking, last drink in hours, cigarettes per week, years spent smoking, hours since last cigarette, HADS-Anxiety and HADS-Depression.

	Binge Drinkers		Non-Binge Drinkers	
	M	*SD*	*M*	*SD*
Age	19.7	1.39	20.7	1.75
Years Drinking	4.54	2.10	3.95	1.57
Last Drink in Hours	81.0	42.3	65.3	25.4
Cigarettes per week	0.37	1.13	0.20	0.89
Hours last cigarette	1.16	4.88	0.05	0.22
HADS anxiety	4.95	3.85	3.30	3.65
HADS depression	2.04	2.61	1.25	2.19

ANOVAs were applied to test for between group differences on the non-memory measures. A series of one-way ANOVAs were applied to the covariates (non-memory measures) including age, years spent drinking, last drink in hours, cigarettes per week, years spent smoking, hours since last cigarette, HADS-Anxiety and HADS-Depression. The ANOVAs revealed a significant difference between the binge drinkers and non-binge drinkers on age ($F(1,42) = 4.36$, $p < .05$). The direction of effect was that binge drinkers were younger (mean = 19.70) than non-binge drinkers (mean**=** 20.70). The ANOVA revealed no significant difference for years spent drinking ($F(1,42) = 1.07$, $p = 0.30$), nor last drink in hours ($F(1,42) = 2.10$, $p = .15$), nor for cigarettes per week ($F(1,42) = 0.96$, $p = 0.33$), nor for years spent smoking ($F(1,42) = 0.31$, $p = 0.57$), nor for hours since last cigarette ($F(1,42) = 1.03$, $p = 0.31$), nor for HADS-Anxiety ($F(1.42) = 2.11$, $p = 0.15$) and nor for HADS-Depression ($F(1,42) = 1.15$, $p = 0.28$).

Table 2

Means and standard deviations for each group 'binge drinkers' and 'non-binge drinkers' on all memory measures, including virtual reality prospective memory (VRPM) measure and the executive function Reverse Digit Span Task (RDS).

	Binge Drinkers		Non-Binge Drinkers	
	M	*SD*	*M*	*SD*
VRPM	5.54	1.41	7.50	1.31
RDS	4.66	0.56	5.60	0.68

To be ultra conservative to control for any variations between the groups, all the covariates were included in the main analysis for VRPM and RDS scores. Two one way ANCOVAs (controlling for age, years spent drinking, last hours drinking, cigarettes per week, years spent smoking, hours since last cigarette, HADS-Anxiety and HADS-Depression) were applied to the VRPM data and RDS scores. This revealed a significant difference on the VRPM scores for the binge drinkers and non-binge drinkers ($F(1,34) = 12.86$, $p<.05$), with binge drinkers recalling fewer items (mean=5.54, SD= 1.41) than non-binge drinkers (mean= 7.50, SD= 1.31). There was also a significant difference between binge drinkers and non-binge drinkers on the RDS scores ($F(1,34) = 11.18$, $p<.05$). Binge drinkers recalled fewer digits (mean=4.66, SD= 0.56) than non-binge drinkers (mean=5.60, SD= 0.68).

In addition to the main analysis a series of Pearson Correlations were applied to the binge drinking data to observe whether there is a relationship between the number of binge drinking sessions and scores on the VRPM and RDS tasks, as well as units drank per session and scores on the VRPM and RDS tasks. This revealed that the number of binge drinking sessions had no significant relationship with the VRPM scores ($r(24) = 0.04$, $p = 0.82$), nor between number of binge drinking sessions and RDS scores ($r(24) = -0.18$, $p = 0.38$). There was a significant negative correlation between the number of units per session and VRPM scores ($r(24) = -0.57$, $p < 0.1$), indicating the more units per session the lower the PM scores. There is also a negative correlation between the number of units per session and scores on the RDS ($r(24) = - 0.29$, $p = 0.16$), however this failed to reach significance. In addition, a univariate ANCOVA was applied to the VRPM scores across binge drinking and non-binge drinking scores controlling for RDS scores. This revealed no significant difference between the binge drinkers and non-binge drinkers on PM scores ($F(1,41) = 3.90$, $p = .055$), suggesting a significant contribution of executive function (RDS) to PM. A univariate ANCOVA was applied comparing the binge and non-binge drinkers on RDS scores, controlling for VRPM scores, this revealed a significant difference between the groups on RDS, regardless of controlling for PM ($F(1,41) = 5.63$, $p < .05$). This suggests executive functioning plays a major contribution in terms of PM functioning.

In summary, findings from this study show that after controlling for age, years spent drinking, last drink in hours, cigarettes per week, years spent smoking, hours since last cigarette, HADS-Anxiety and HADS-Depression there were significant differences between binge drinkers and non-binge drinkers on the VRPM task (measuring PM) and RDS task (measuring executive function) scores. Those findings indicated poorer performance of PM and executive function in binge drinkers compared with non-binge drinkers. After controlling for RDS scores on the VRPM data between the groups the significant difference disappeared on the VRPM data. However, when controlling VRPM scores on the RDS data between the groups the significant difference remained. This finding suggests executive function plays a key underlying role in PM. (For a full SPSS output see appendix 10, for raw data see appendix 11).

DISCUSSION

The present study had two main aims relating to binge drinking in a young adult cohort. Firstly, to assess whether binge drinking impairs prospective memory (PM) performance in young adults, and secondly to determine whether a binge drinker

who has an impaired PM, has related impairments in their executive function. With regards to the first aim the findings showed that binge drinkers remembered significantly fewer PM items during the Virtual Reality Prospective Memory (VRPM) task compared to non-binge drinkers, indicating that poorer PM performance is associated with binge drinking. With regards to the second aim the findings showed that, in comparison with non-binge drinkers, the binge drinkers recalled significantly fewer digits on the Reverse Digit Span (RDS) task indicating impairments in their executive function. In addition, concerning the relationship between PM and executive function, the findings demonstrated that when a univariate ANCOVA was applied to the binge drinkers and non-binge drinkers VRPM scores controlling for the RDS scores, there was no significant difference between the groups on the VRPM. An important finding was that when the univariate ANVOCA was applied comparing the binge drinkers and non-binge drinkers on RDS scores controlling for VRPM scores a significant difference remained between the groups on the RDS scores, indicating that executive functioning plays a key role in PM performance. These findings were observed after controlling for age, years spent drinking, last cigarette in hours, cigarettes per week, years spent smoking and anxiety and depression scores.

The significant finding that binge drinkers scored lower on the VRPM task (measuring PM) compared to the non-binge drinkers confirms the prediction that binge drinking in young adults impairs their prospective memory. This finding is consistent with previous research by Heffernan et al., (2010) and Heffernan and O'Neill (2012), the only two studies to date revealing that binge drinking has adverse effects upon PM. The current study has provided convergent evidence that PM deficits are associated to binge drinking. The present research employed an improved objective measure of PM to overcome methodical issues (identified earlier in the introduction) associated with the Prospective Remembering Video Procedure (PMVP) used in Heffernan et al., (2010), and the Cambridge Prospective Memory Test (CAMPROMPT) used in Heffernan and O'Neill (2012). The objective measure of PM used within the present study was the Virtual Reality Prospective Memory (VRPM) task. The VRPM task was a reliable objective measure of PM. Unlike the PMVP and CAMPROMPT the VRPM prospective memory items were akin to the real world and subjects had complete control of their environment which meant the task more ecologically valid. In addition, it was observed that the increased number of alcoholic units consumed per session by the binge drinkers was associated with poorer PM performance on the VRPM task. A similar observation was made by Heffernan et al., (2010), although it was found that the increased number of units consumed per week correlated with poorer PM performance. Taken together, these findings suggest dose-related deficits in binge drinker's prospective memories. The findings of the current research and those of Heffernan et al., (2010) and Heffernan and O'Neill (2012) confirm that binge drinking has adverse effects on PM. Future research could explore dose related deficits in more detail. Participants could fall into 'light', 'moderate' or 'heavy' dose categories depending on the number of units consumed, in a given time period. It would be expected that the more units (higher dose of alcohol consumed), the poorer the PM functioning.

Concerning the second aim of the present study, the finding that binge drinkers achieved significantly lower scores on the Reverse Digit Span (RDS) task compared to non-binge drinkers confirms the prediction that binge drinkers who have an impaired PM will have associated deficits in their executive functioning. The second prediction of the study was expected because previous research suggested that the

PFC of the brain is responsible for both PM (Blume and Marlatt, 2009) and executive functioning (Courtney and Polich, 2009). Since previous research indicates that binge drinking can have damaging and harmful effects on the PFC (Duka and Scaife, 2009), an area of the brain that is responsible for executive functioning, it could be anticipated that the binge drinkers would perform worse on the RDS (measuring executive function). The finding that binge drinkers have impairments in their executive functioning is consistent with a number of previous studies. Similar to the present research, Parada et al., (2011) analysed the relationship between binge drinking and executive functions subserved by the PFC in university students. They also employed the RDS task as a measure of executive functioning, and found that binge drinking subjects recalled significantly fewer digits compared with the non-binge drinking controls. In addition, Garcia-Moreno et al., (2008) found that subjects who were moderate (4 drinks or more on a single occasion) or abusive (5 drinks or more on a single occasion) binge drinkers showed poorer performance on tasks that relied on correct executive functioning compared to subjects that drank no alcohol. Research by Weissenborn and Duka (2003) also found that binge drinkers compared to non-binge drinkers were impaired on executive functioning tasks, thought to reflect frontal lobe function. The findings of the present study provide further evidence that binge drinking is associated with poorer performance of executive functions subserved by the dorsolateral pre-frontal cortex.

It is possible that damage to the prefrontal cortex is caused by excessive alcohol consumption explains the deficits in PM. This is particularly plausible given the research by Okuda et al., (1998) who suggest that pre-frontal and frontal lobes of the brain provide the anatomical basis for PM. Using positron emission tomography (PET) Okuda et al., (1998) found several localized activations in the PFC of subjects who were engaging in tasks that relied on PM functioning. Taking this into account, it is noted that binge drinkers have been shown to have smaller PFC volumes than non-binge drinkers (Courtney and Polich, 2009). It is therefore feasible that a smaller PFC volume size, resulting from white matter loss, negatively effects PM functioning. According to McFarland and Glisky (2009) previous research has shown that patients with damaged frontal lobes have shown observable impairments in their PM when carrying out tasks such as maintaining an intention, dividing the attention between tasks, monitoring the environment or a cue and inhibiting on-going activities. This is further evidence that deficits in PM are a result of the consequences of binge drinking on the PFC. Given the present findings and the previous research mentioned above, it is plausible that binge drinkers have deficits in their PM and executive functions, because both memory processes are sharing pre-frontal and frontal lobe resources.

No research to date has explored the relationship between PM and executive functioning in binge drinkers. A main strength of the current study is that the findings clearly show PM and executive functioning deficits in the same cohort. In addition, a novel finding was that executive functioning has been shown to underpin PM. The results from the present study indicate that executive functions are fundamental underlying mechanisms in PM function. Evidence from previous research also suggests that PM processes depend heavily on executive functioning. Groot, Wilson, Evans and Watson (2002) found that better executive functioning was significantly associated with better PM performance when analysing the data of PM and executive function tasks. It was also found that subjects performed more poorly on time-base PM tasks than event-based PM tasks. Groot et al., (2002) suggested that

there might be a higher demand on executive control during the time-based PM tasks, making them more difficult than the event-based PM tasks suggesting that executive functioning plays a crucial role in PM. Kliegel et al., (2008) has suggested that PM performance is especially sensitive to executive dysfunction and impairments in executive functioning have found to result in diminished abilities to perform PM tasks. Heffernan, Ling and Bartholomew (2004) also demonstrate a link between PM and executive function. Using self report measures, excessive alcohol users reported more deficits in their PM and executive functioning processes than low dose or no alcohol users. With regards to the findings of the present study and previous research mentioned above, it seems that PM processes are lowered by the disruptions in executive functioning caused by binge drinking. These findings support evidence to suggest that PM and executive functions share PFC recourses, since deficits have been found in the same cohort for each memory process.

An ethical consideration is whether one should enlighten the binge drinkers in this study of the apparent damage to their cognitive functioning, with an aim that they should from abstain from binge drinking. A restudy of the present research could be held in one years time having encouraged participants to abstain from binge drinking and it could then be investigate whether their PM and executive functions are irreversibly damaged. Failures in prospective memory and executive functioning could threaten independent living. For this reason, it is extremely important that the hazardous effects of binge drinking are well recognised. The findings of this study could have wider range of implications. Given that health related professionals have limited knowledge about the consequences of binge drinking (Heffernan, 2008), the present research could provide them with a broader understanding of the cognitive disabilities that binge drinkers might face. The greater the insight into the consequences of binge drinking that the health professionals gain, the better informed the members of the public or those in education will be. In addition, there is a clear need to educate children earlier. According to the NIAAA (2012), children as young as 12 are engaging in binge drinking activities. The present research could help pre-empt the binge drinking culture in children. Educational based interventions and health related campaigns need to be aware of the wider research on binge drinking. Offering such informative knowledge to children, adolescents, young adults and society in general, would hopefully change the way individuals think about alcohol as they are made fully aware of the detrimental effects that binge drinking could have on them.

Although the current research has provided further evidence concerning the adverse effects that binge drinking has on PM and related executive functioning, it does suffer from some limitations and several methodical issues should be addressed. The Virtual Reality Prospective Memory (VRPM) task has proven to be a reliable measure of PM. The fundamental idea of the VRPM task is as such that it creates a ‘real world’ environment and is composed of ‘real world’ PM tasks to complete. However, since the VRPM is not an actual real world PM task, future research should access binge and non-binge drinkers while they complete PM tasks in a real world situation and hence increase ecological validity as it would be a better representation of a true life situation. To test the true impact of binge drinking on PM, participants could be asked to remember PM tasks while they walk down a busy shopping high street and in this way, genuine environmental distractors could come into play. Another methodical weakness of the VRPM is that the task lasts a mere 8 minutes, which is not long enough to cover a range of PM activities that a person

may experience on a day to day basis. The Reverse Digits Span (RDS) task used in the current study is a reliable measure of executive function and has been used successfully in much previous research. However, there are a wide range of executive functioning tests that could be used as alternative or additional measures to the RDS task (Baddeley, 2002). Further research could apply alternative measures of executive functioning alongside measures of PM, whist exploring the adverse effects of binge drinking on these two important memory processes. The self report Recreational Drug Use Questionnaire (RDUQ) can be problematic, with respect to the honesty and accuracy of participants. An alternative here would be to employ biological drug screening methods, which would provide a more accurate measure of drinking behaviour and other drug use in participants. In addition, this would also help define binge drinking groups more clearly, which would give a better indication into which category (binge drinking or non-binge drinking) they fall into. The current research could be extended in several ways. An investigation into binge drinking related deficits in PM and executive functioning could be carried out using a neuroimaging technique such as fMRI (functional magnetic resonance imaging) to detect changes in cerebral blood flow (activations) in the brain. Participants could perform PM tasks alongside executive functioning tasks while undergoing an fMRI scan of their prefrontal cortex (PFC). It would be expected that binge drinkers would exhibit reduced levels of activations in the areas responsible for PM and executive functioning in their PFC compared to non-binge drinking controls. In addition, this method would help determine the exact regions responsible for PM and executive functioning, and one could observe if there is an overlap between the regions responsible for these two memory processes. The NIAAA (2012) suggests binge drinkers are more likely to use other drugs such as cannabis or cocaine. Previous research has shown that PM deficits have been associated with the use of ecstasy and cannabis (Heffernan, Ling and Scholey, 2001; Rodgers, Buchanan, Scholey, Heffernan, Ling and Parrott, 2001). Future research could explore the effects that poly drug use (binge drinking, ecstasy and cannabis) has on PM and related executive functioning. Groups could be composed of ‘binge drinkers and other drug use’, ‘binge drinkers and no drug use’ and ‘non-drinkers and no drug use’. One might expect that a combination of drug substance would have the greatest impact on PM and related executive functions. Finally, a matter that should be further discussed is the many different definitions of binge drinking (Courtney and Polich 2009). A limitation here is that it is not so clear when drinking becomes binge drinking. If research on binge drinking is to be universally understood and applicable, then an equally universal definition is needed.

In conclusion the current research set out to investigate the adverse effects that binge drinking in young adults has upon their PM and related executive function. The finding that binge drinking significantly impairs PM and executive functioning, supports previous research in the area. A truly novel finding of the current research showed that executive functioning underpins PM processes. This research provides evidence to support the idea that executive functioning is fundamental to PM and further research needs to be conducted to support and extend the current findings.

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