

The Impact of Excessive Alcohol Use on Prospective Memory: A Brief Review

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Abstract: Research into the cognitive consequences of chronic excessive alcohol use continues to grow. Despite this, little research has investigated what impact excessive alcohol use might have upon everyday remembering. An important aspect of everyday remembering is prospective memory (PM), which refers to the cognitive ability of remembering to carry out an intended action at some future point in time. The majority of the studies which have focused on what impact excessive alcohol use has upon PM in teenagers and young adults have consistently found that the excessive drinkers reported more lapses in their short term (e.g., forgetting to lock one's door upon leaving home) and long term (e.g., forgetting to post a letter on time) aspects of everyday PM, when compared to low-dose alcohol users or non-users. It is concluded from this review that PM deficits should be added to the growing list of neuropsychological sequelae associated with excessive alcohol use. The magnitude of the effects of alcohol on PM depends upon the amount of alcohol consumed and how long one has been drinking. Major limitations of these studies include their reliance upon the use of self-report measures of PM, the issue of polydrug use complicating the picture, the need to control for the co-morbidity of other conditions - such as depression, and better drug-screening methods. Therefore, further studies need to employ objective measures alongside self-report measures of PM, incorporate better controls for the use of other drugs and mood states, as well as extending the focus of the research to study what effect different patterns of alcohol use might have upon PM, e.g., what impact binge drinking has upon everyday PM. These findings have educational and applied relevance within the alcohol field.

Keywords: Excessive alcohol, teenagers, young adults, prospective memory.

1. PREVALENCE OF ALCOHOL USE AND MISUSE

Alcohol is perhaps the most commonly used 'recreational drug' in Western societies, with estimates of 90% of people consuming alcohol at some stage in their lives and with an estimate of 30% going on to develop some form of alcohol-related disorder [1]. When used in moderation, alcohol can have beneficial effects [2], but when abused can lead to a range of physiological and cognitive problems [1]. The current cut-off limits for safe drinking recommended by the United Kingdom (UK) Government are set at 21/14 units for males/females respectively (or 7.20/4.80 US fluid ounces of ethanol respectively) i.e., before it poses a threat to one's health [3]. Alcohol misuse is on the increase in young adults and teenagers, for example, there is an increase in the prevalence of 'binge drinking' (drinking in excess of 5 units of alcohol in one or more sessions across a week), with various surveys showing that this type of excessive drinking is amongst the highest in the 16 to 24 year old age group [4, 5] and then decreases with age. In addition, research has shown that in excess of 44% of college students' binge-drink every two weeks and 19% being frequent binge drinkers, having more than 3 binge-drinking episodes per week [6]. Given the increasing prevalence of excessive drinking in young adults and teenagers, it is important to understand what impact this

pattern of drinking might have upon brain functioning and related cognitive processes that facilitate everyday living.

2. PUTATIVE BRAIN DAMAGE ASSOCIATED WITH EXCESSIVE DRINKING IN ADULTS AND TEENAGERS

In adults, persistent misuse of alcohol can result in damage to a range of cortical and sub-cortical structures of the brain, can lead to brain shrinkage, neurotransmitter impairments, inhibition of frontal cortex functioning and reduced hippocampal function (see e.g., [7-11]). For example, in adults it is known that alcohol causes brain shrinkage, particularly in alcohol-dependent people where the damage induced may be permanent [8]. Animal research has revealed that alcohol has been found to reduce the number of cholinergic neurons in the basal forebrain leading to reduced hippocampal function - a structure heavily implicated in memory consolidation [7]. Alcohol also appears to inhibit prefrontal lobe functioning [9] and in extreme cases (e.g., in Korsakoff patients) can lead to cerebral atrophy [10]. In a recent review of Neuroimaging studies focusing upon the effects of excessive alcohol use on the neurocircuitry of the brain, a compelling argument was made for the central role of a degradation of the frontocerebellar neuronal nodes and connecting circuitry affecting widespread regions of the brain, resulting in widespread cognitive deficits including motor, visuo-spatial and executive processes [12]. Excessive drinking among teenagers is particularly troubling given recent evidence that suggests a tremendous amount of structural and functional changes that take place during the teen-

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age years (see e.g., [13-22]). For example, magnetic resonance imaging (MRI) studies have demonstrated an increase in the gray matter volume of the brain during the late teenage years, with a post teenage decrease [15]. During this 'spurt' these changes correspond to a marked increase in axons at the cellular level, with a rapid pruning in the latter teenage years [15, 16]. The prefrontal cortex and the limbic system, which includes the hippocampus, undergoes prominent reorganisation during this time [13, 19], and those cognitive processes that rely on these areas of the brain, such as memorial processes, are very sensitive to any damage caused by excessive alcohol ingestion.

The neural effects of acute alcohol ingestion are not yet fully elucidated. In animal studies focusing on rats, there is evidence that alcohol suppresses the function of pyramidal cells in the hippocampus that are implicated in forming new memories. A second mechanism that is adversely affected is the process of Long-Term Potentiation (LTP) mediated by the hippocampus in humans, probably *via* alcohol blocking NMDA receptors, resulting in a failure to form long-term memories (it is important to note that this effect does not occur before alcohol ingestion or after the alcohol has left the system) [10]. Research using positron emission tomography has also demonstrated that acute alcohol ingestion in 'social drinkers' reduces blood flow to key parts of the brain, such as the cerebellum, and interferes with the metabolic activity of the brain [23]. It is also feasible that increasing levels of alcohol ingestion interferes with communications between a range of key parts of the brain.

3. COGNITIVE AND MEMORY DEFICITS ASSOCIATED WITH EXCESSIVE DRINKING IN ADULTS AND TEENAGERS

Chronic heavy alcohol consumption (ingesting above the 21/14 units recommended for males/females respectively) leads to a number of neuropsychological impairments in adults and teenagers, including memory deficits [24-34]. For example, chronic heavy alcohol users and alcohol-dependent individuals show impaired performance on tasks including learning word lists, short- and long-term logical memory, general working memory and executive function (e.g., [24, 25, 29, 31]). Research into neurocognitive function in teenagers with a history of alcohol abuse has revealed deficits on a range of verbal and non-verbal memory tasks, language and attentional tasks, and specific working memory impairments (e.g., [26, 30, 32, 33]). Research into the acute alcohol effects on cognitive function has revealed a range of cognitive deficits, including memorial deficits, for example, deficits in attention, explicit memory paradigms, and more recently executive-type functions [35].

Such research into memory dysfunction has tended to focus on laboratory and/or field tests of retrospective memory - encompassing the learning, consolidation, retention and retrieval of previously presented target material. However few investigations have examined the extent to which these impairments impact upon everyday memory functioning, of which prospective memory is an important aspect [36].

4. WHAT IS PROSPECTIVE MEMORY?

Prospective memory (PM) is the cognitive ability to remember to carry out some activity at some future point in time, for example, remembering to attend an appointment at the dentist, remembering to take one's medication on time,

or remembering to carry out a task such as remembering to pay a bill on time [37]. PM is essential for everyday life, since the need to prospectively remember things is ubiquitous in everyday life. Diminished prospective memory abilities can have serious consequences for everyday living. For example, persistent failures in PM can impede one's professional activities (e.g., regularly forgetting activities one is supposed to carry out at work), can place a strain on personal relationships (e.g., constantly forgetting to meet with friends at agreed times), and can have a serious impact upon one's physical health (e.g., forgetting to take some important medication on time). In sum, diminished PM abilities can be embarrassing, can endanger one's professional standing, or have serious personal consequences on one's well being.

5. PROSPECTIVE MEMORY DEFICITS ASSOCIATED WITH EXCESSIVE DRINKING IN ADULTS AND TEENAGERS

5.1. PM Deficits and Excessive Drinking in Adults

An initial study investigated PM deficits in amnesic Korsakoff patients and non-amnesic controls [38]. Korsakoff patients are known to suffer from a general cerebral atrophy and particularly from frontal lobe atrophy. Since PM is believed to rely heavily upon the pre-frontal and frontal lobes [39-41], the Korsakoff patients were expected to show considerably impaired prospective memory when compared with the non-amnesic controls. Korsakoff patients did perform worse on the tasks, although it was difficult to determine whether the memory deficits observed were attributable to either the prospective or retrospective elements of the tasks [38]. Recent studies have assessed PM functioning in excessive drinkers (using non-clinical samples) and compared performance with low-dose/zero-alcohol groups using the Prospective Memory Questionnaire (PMQ: 42). The PMQ contains three sub-scales that provide self-reported measures of short-term habitual PM (e.g., "I forgot to turn my alarm clock off when I got up this morning"), long-term episodic PM (e.g., "I forgot to pass on a message to someone"), and internally-cued PM (e.g., "I forgot what I wanted to say in the middle of a sentence"). The scale ranges from 1 (where least forgetting is evident) to 9 (where there is a great deal of forgetting reported), with the greater the score, the more faulty one's prospective memory. In addition, the PMQ gauges the number of strategies used to aid remembering *via* the Techniques to Remember Scale (e.g., "I make lists of things I need to do"). On this latter scale, the higher the score the more memory strategies/aids used.

In the first of this line of research [43] excessive alcohol users (ingesting above the 21/14 units for males/females respectively) were compared to low-dose/zero-user controls on the PMQ. After statistically controlling for age, other drug use and strategy use, chronic heavy alcohol users showed global impairments in PM, i.e., reported more memory lapses on all three PM sub-scales of the PMQ, when compared to matched controls. In a second study [44] a world-wide-web design was used to access in excess of 700 participants who were either zero-alcohol users, low-dose users (ingesting 1-9 units of alcohol per week), medium users (ingesting 10 - 25 units of alcohol per week), or excessive users (ingesting 25+ units of alcohol per week). In this study, two

self-report measures were used; one used to assess prospective memory (using the PMQ) and a second that gauged general everyday memory (EM) using the Everyday Memory Questionnaire (EMQ: [45]) which is a measure of common memory lapses in everyday activities. After statistically controlling for age, other drug use and strategy use, there was evidence that excessive use of alcohol was associated with impairments in the long-term aspect of prospective memory on the PMQ and with an increased number of cognitive failures on the EMQ. There was also a dose-dependent increase in PM and EM lapses evident, with more lapses reported as the amount of alcohol used increased. Importantly, a recent study [46] found that the PM impairments reported by chronic excessive alcohol users (utilising the PMQ) was accompanied by self-reported impairments in executive functioning on the Dysexecutive Questionnaire (DEX: [47]). Moreover, although excessive alcohol users report greater PM impairments than matched controls, they do not appear to use sufficient internal/external memory strategies to compensate for these deficits (see e.g., [43, 44, 46]).

5.2. PM Deficits and Excessive Drinking in Teenagers

Recent research has compared excessive drinking in teenagers (ingesting above the 21/14 units for males/females respectively) with low-dose/zero-users utilising the PMQ as a self-report measure of PM. Only two studies to date has focused on what impact excessive drinking might have upon everyday remembering in teenagers and both of these have utilised the PMQ as a measure of everyday PM. In two separate studies [48, 49] the PMQ was used to compare excessive teenage alcohol users with non-drinking/low-dose alcohol controls aged 16 – 19 years. After matching for age and statistically controlling for other drug use and strategy use, both studies consistently found that the excessive drinkers reported more lapses in their short term (e.g., forgetting to lock one's door upon leaving home) and long term (e.g., forgetting to post a letter on time) aspects of everyday PM, when compared to the controls.

It should be noted that, to date, there is no published research that has compared the effects of acute versus chronic alcohol use in relation to PM processes, nor in relation to whether abstinence from alcohol use leads to improvements in PM functioning.

There is therefore much scope for further research in these areas.

5.3. Putative Mechanisms Underlying PM Deficits Associated with Excessive Drinking in Adult and Teenage Cohorts

The precise mechanisms underlying the observed PM deficits associated with excessive alcohol use in young adults and teenagers are not fully understood at present. Damage to cortical and sub-cortical structures, including the hippocampus, pre-frontal and frontal cortices, could explain the PM impairments observed in the studies reviewed here. Recent studies using brain imaging techniques have attempted to 'map' those brain sites implicated in prospective remembering. It has been suggested that specific sub-processes of prospective memory strongly rely on the prefrontal cortex – involved in the planning and initiation of an intended action, and the medial tem-

poral lobes – involved in the retrieval of detailed information about the content of the to-be-recalled information, as well as interactions between these structures (see e.g., [50, 51]). However, it is unclear as to precisely which component(s) of prospective remembering and its associated brain sites might be damaged by prolonged alcohol misuse. It is also possible that a complex interaction between the putative depletion of specific neurotransmitter substances known to impact upon mnemonic processes, such as serotonin [52, 53] and damage to specific regions of the brain may account for the PM deficits observed. Further research is needed to clarify the relationship between chronic heavy alcohol use, impairments in prospective memory and the neuropsychological basis for such impairments.

It is important to bear in mind that the impact of alcohol misuse upon brain function and associated cognition will be dependent upon a number of factors. For example, how much and how often the person drinks, the age at which s/he began drinking, the person's age, level of education, socio-economic background, genetic and family background, the person's general health status and 'lifestyle variables'. Thus, there is a wide variability in the type/degree of damage and associated cognitive dysfunction.

6. LIMITATIONS OF METHODS USED IN RESEARCH

There are a number of limitations within this field of research. *The use of self-reports* of memory are problematic, since people may overestimate or underestimate their own memory capabilities [54, 55]. Self-perceptual biases is particularly pertinent in the field of recreational drug use and memory, where one is asking excessive alcohol users (suspected of having poor memories) about their own memory capabilities – resulting in a type of 'memory paradox'. Self-report measures, such as the PMQ, should therefore be used alongside other measures of PM, such as objective laboratory-based tasks and video-based PM scenarios, a move recommended by current researchers [56, 57]. *Self-reported drug use* can also be problematic, again relying on the honesty and accuracy of the participant. Biological drug-screening methods would be preferable, providing a more accurate measure of drug use and providing the opportunity to screen out participants who are using drugs other than alcohol, rather than statistically controlling for such use. However, these methods can be expensive and time-consuming. *The use of the world-wide-web approach* can have the advantage of accessing large sample sizes, but there are a number of problems associated with this approach. For example, the www approach can mean that one is less likely to gain access to particular subgroups within society, such as older people, depending upon their information-technology skills and access to facilities. This can lead to possible biases in sampling and should be noted when interpreting the findings from www studies [58]. *Levels of depression* should also be controlled for, given the link between mood states, drug use and memory, particularly self-reported memory capabilities [59]. Further limitations of past research in this area includes a lack of screening for other mental disorders (apart from depression), the difficulty in accessing otherwise 'drug free' alcohol user groups and controls (i.e., who do not use other recreational substances, including smoking), and a lack of control for a range of variables believed to impact upon cognition and memory, such as pre-morbid intelligence,

general IQ, as well as a wide range of demographic, biological and 'life-style' factors [60].

7. AREAS FOR FUTURE RESEARCH

Despite these limitations there is plenty of scope for further work in this field. Future research should extend the methods used to assess the links between excessive alcohol use and deficits in prospective memory to include objective measures, such as laboratory-based tasks, video-based scenarios or real-life observations of everyday PM (e.g., the use of diary studies), in order to provide converging evidence for the findings from the studies reviewed here and extend the focus further [36, 56]. Future research might also wish to assess putative PM deficits associated with 'binge drinking' in young adults and teenagers, an area that is of growing concern in the UK and other countries around the world [61], particularly since binge drinking is most prevalent in young adults and teenagers. Related to this latter point, future research should assess what impact drinking during pregnancy might have upon everyday cognitive abilities (such as PM) in the developing child, given the growing concerns about foetal alcohol syndrome and other related developmental disorders [62]. Future research should also explore whether low/moderate doses of alcohol actually improves everyday PM when compared to non-users, given that some evidence suggests that low doses of alcohol might actually enhance cognition [60]. As stated earlier, there is much scope for research comparing acute versus chronic alcohol use in relation to PM processes in order to assess what impact different patterns of alcohol use might have upon everyday PM. The co-morbidity of alcohol misuse and other drug use should also be assessed in relation to PM in order to determine the relative contributions of different drugs to putative PM deficits. The links between PM deficits and deficits in other key memorial processes such as central executive deficits observed in previous research [46] should be explored further using a range of measures. The impact of 'protective factors' such as a healthy diet, exercise, water intake following alcohol ingestion, socioeconomic factors, and general 'life-style' variables, and so on, should also be explored in order to assess whether they off-set any potential deficits in everyday cognition associated with excessive drinking. Finally, the impact of abstaining from excessive alcohol use could also become a focus of research in order to observe whether there is any recovery of function in PM performance following a period of abstinence.

8. OVERALL CONCLUSIONS

The findings from the range of studies reviewed here into the impact of excessive drinking upon young adults' and teenagers' PM abilities supports the notion that excessive drinking leads to impairments in everyday PM. It is argued here that these deficits need to be added to the growing list of neuropsychological sequelae associated with excessive drinking in young adults and teenagers. At a more applied level, the findings from the studies reviewed here may have implications for the management and treatment of young adults and teenagers who misuse alcohol, but who are at a sub-clinical level. The reduced level of everyday memory functioning observed in excessive alcohol users and their failure to compensate by utilising sufficient strategies to aid such deficits could affect

their academic and vocational pursuits, as well as their everyday living.

An understanding of the limitations these people face will be of relevance to health care professionals, such as Doctors and Nursing staff dealing with such individuals, perhaps encouraging compensatory mechanisms in the form of increased strategy use to bolster their memories, for example, using a diary to remind them of key appointments, or the use of various mnemonic strategies to aid memory functioning. Management of the memory problems at this level may prove beneficial to the age range affected and may help to educate them in terms of the damage caused by prolonged alcohol misuse. A major challenge is to use such knowledge in prevention campaigns and to better inform medical and nursing staff of the everyday cognitive difficulties young adults and teenagers with drinking problems face, in order to equip medical and nursing staff with more knowledge and skills in their professional practice. Indeed, the Department of Health and Social Security (DHSS) in the UK has highlighted the fact that health professionals, such as nursing staff, may be hindered in their attitude towards, and response to, patients presenting with drug-related problems due to their lack of knowledge about the difficulties arising from patients who abuse drugs, including alcohol [63]. To reinforce this point, the National Treatment Agency for Substance Misuse in the UK has published a framework for guidance to nursing staff and other health care workers on improving knowledge about drug misuse and the problems patients face as a result of the drug abuse, as well as developing effective management systems in the UK to deal with the direct and indirect impact of drug misuse in patients [64]. Prospective memory is essential for independent living and deficits in this aspect of memory as a result of misusing alcohol may have disastrous consequences for the individual.

Key Learning Objectives:

- The aim of this review is to highlight recent knowledge of everyday prospective memory (PM) deficits associated with chronic excessive alcohol use in teenagers and young adults.
- The findings from the majority of studies have shown that excessive drinking results in short-term and long-term everyday PM deficits in teenagers and young adults.
- The PM deficits observed may be the result of damage to selective parts of the brain, including the medial temporal lobes and the pre-frontal cortex.
- Limitations in this field of research include the reliance upon self-report measures of PM, as well as the co-morbidity of other drugs and other psychological conditions.
- Further research is needed to clarify the relationship between excessive alcohol abuse and the neuropsychological impairments underpinning the PM deficits observed.

Future Research Questions:

- What impact does 'binge drinking' have upon everyday prospective memory?
- Are prospective memory deficits observable in children and adults suffering foetal alcohol syndrome?
- Does abstaining from alcohol use lead to a recovery of function in prospective memory?

ABBREVIATIONS

EM	=	Everyday Memory
EMQ	=	Everyday Memory Questionnaire
DEX	=	Dysexecutive Questionnaire
DHSS	=	Department of Health and Social Security
MRI	=	Magnetic Resonance Imaging
PM	=	Prospective Memory
PMQ	=	Prospective Memory Questionnaire
UK	=	United Kingdom
www	=	Worldwide web

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