Neuropsychopharmacology (2003) 28, 740–746

www.neuropsychopharmacology.org

Alcohol Hangover Effects on Memory Functioning and Vigilance Performance after an Evening of Binge Drinking

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The impairing effects on memory functioning after acute alcohol intoxication in healthy volunteers and after chronic use in alcoholics are well established. However, research determining the next-morning effects of a single episode of binge drinking on memory functioning is scarce. A total of 48 healthy volunteers participated in a single-blind study comprising an evening (baseline) session, followed by a treatment administration (ethanol 1.4 g/kg or placebo), and a morning session. Memory was tested with a word-learning test (including immediate and delayed recall, and recognition). Further, a 45-min Mackworth clock test for measuring vigilance was included (parameters: number of hits and false alarms) and subjective alertness was assessed, to infer whether word-learning test findings reflect sedation or specific memory impairments. Delayed recall in the morning session was significantly worse in the alcohol group when compared to the placebo group ($F_{1,42} = 6.0$, $p < 0.02$). In contrast, immediate recall and recognition were unimpaired in the alcohol group. In the morning session, relative to the placebo group, subjective alertness was significantly reduced in the alcohol group before and after the tests ($F_{1,44} = 8.7$, $p < 0.005$; $F_{1,44} = 13.3$, $p < 0.001$, respectively). However, in the Mackworth clock test, the alcohol group and placebo group did not differ significantly in the morning session. The specific findings of impaired delayed recall show that memory retrieval processes are significantly impaired during alcohol hangover. Vigilance performance was not significantly affected, indicating that this memory impairment does not reflect sedation.
Neuropsychopharmacology (2003) **28,** 740–746. doi:10.1038/sj.npp.1300090

Keywords: alcohol; hangover; memory; vigilance; binge drinking.

INTRODUCTION

Alcohol hangovers are next-morning adverse effects that occur after an evening of binge drinking, that is, drinking more than four (women) or five (men) drinks on one occasion. When hangover symptoms start to occur, blood alcohol concentration (BAC) is normally (close to) zero. The hangover state continues up to 24 h after awakening (Swift and Davidson, 1998), and is characterized by a variety of symptoms, including sleepiness, drowsiness, concentration problems, lightheadedness, dry mouth, and nausea. The severity of these symptoms varies between and within subjects, for example depending on the type of alcoholic beverage, the presence or absence of congeners (Pawan, 1973), the amount of alcohol consumed, drinking pattern, and drinking history. The actual cause(s) of hangover are yet unknown, but a relation with the toxic effects of one of ethanol's major metabolic products, that is, acetaldehyde (Swift and Davidson, 1998; Wiese *et al*, 2000), has been suggested, since acetaldehyde produces effects similar to adverse effects observed in the alcohol hangover state. In addition, several other factors have been suggested to contribute to alcohol hangover, including dehydration, electrolyte imbalance, gastrointestinal disturbances, low blood sugar levels (hypoglycemia), and sleep and biological rhythm disturbances (Swift and Davidson, 1998).

Alcohol hangover effects cause serious economic consequences. Hangover-related absenteeism and poor job performance costs the US economy about $148 billion a year (Stockwell, 1998). Workers with an alcohol hangover reported significantly more conflicts with supervisors and co-workers, and felt miserable or fell asleep on the job (Ames *et al*, 1997). Also, physical performance of healthy volunteers (Karvinen *et al*, 1962) and athletes (O'Brien and Lyons, 2000) is significantly reduced during hangover. Binge drinking is especially prevalent among college students. Since three out of five college students are regularly involved in binge drinking, it is the most serious public health problem of American colleges (Wechsler *et al*, 1998, 2000).

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Received 30 May 2002; revised 30 September 2002; accepted 2 October 2002
Online publication: 8 October 2002 at http://www.acnp.org/citations/Npp10080240l

In general, but especially for college students, proper memory functioning is essential to perform daily activities requiring the ability of learning and remembering. Memory can be distinguished in declarative and procedural memory. Procedural memory refers to learned procedures, expressed in acquired skills. Declarative memory comprises acquisition, retention, and retrieval of events (episodic memory) or facts (semantic memory) that can be measured by direct or indirect tests of memory, such as free recall, cued recall, or recognition (Gabrieli, 1998). Declarative memory can be further divided into short-term memory processes (generally tested within 10 min after learning) and long-term memory processes (generally tested 30 min up to days after learning). For example, in the word-learning test, after learning a list of words (acquisition), the learned words may be transferred to a long-term storage (consolidation). Retrieval of learned words from this long-term storage can be without cues (free delayed recall) or by means of cued recall (recognition).

Memory and psychomotor impairment during alcohol intoxication has been consistently reported (Krüger, 1992; Ferrara *et al*, 1994; Holloway, 1995; Koelega, 1995; Moskowitz and Fiorentino, 2000). Studies performed with alcoholics showed that frequent binge drinking also produces serious memory deficits in the long run (eg Tapert *et al*, 2001). Moreover, a recent study performed in rats showed that even after a 4-day period of continuous binge drinking, significant corticolimbic neural cell loss was observed (Obernier *et al*, 2002). During hangover, these rats performed significantly worse on spatial and reversal memory tests, when compared to predrinking assessments.

Surprisingly, alcohol hangover studies in men failed to find significant impairment on memory functioning (Myrsten *et al*, 1980; Chait and Perry, 1994; Finnigan *et al*, 1998). Confusingly, some studies reported significant psychomotor performance impairment (Takala, 1958; Kelly *et al*, 1970; Seppälä *et al*, 1976; Bonte and Volck, 1978; Myrsten *et al*, 1980; Laurell and Törnros, 1983; Yesavage and Von Leirer, 1986; Roehrs *et al*, 1991; Yesavage *et al*, 1994; Anderson and Dawson, 1999), whereas other studies did not (Carroll *et al*, 1964; Ideström and Cadenius, 1968; Dowd *et al*, 1973; Collins and Chiles, 1980; Collins, 1980; Morrow *et al*, 1990; Törnros and Laurell, 1991; Lemon *et al*, 1993; Chait and Perry, 1994; Streufert *et al*, 1995; Taylor *et al*, 1996; Finnigan *et al*, 1998). Taking into account that the majority of participants in these studies *did* report hangover symptoms, the inconclusive results are rather unexpected.

Methodological shortcomings possibly account for these contradictory results. Some of these studies measured alcohol hangover effects while BAC had not yet reached zero (Takala, 1958; Dowd *et al*, 1973), did not report the peak BAC after drinking (Carroll *et al*, 1964; Finnigan *et al*, 1998; Anderson and Dawson, 1999), or BAC at testing times (Carroll *et al*, 1964; Anderson and Dawson, 1999). Interpretation of results from studies with unknown BAC levels at testing time or in the case that BAC was not zero is difficult, since it remains unclear as to whether impairment is caused by hangover effects or the ongoing alcohol intoxication. Further, peak BAC after drinking gives an impression of the severity of hangover, and the sensitivity of the subjects to the effects of alcohol. Another problem includes the absence of controlled intake (Carroll *et al*, 1964; Finnigan *et al*, 1998), since in such instances one cannot be sure that the beverage was actually consumed.

Other studies did not perform blinded treatment administration (Laurell and Törnros, 1983; Törnros and Laurell, 1991; Chait and Perry, 1994). As a result, participants were aware of the alcoholic content of the beverages they consumed. It is likely that this knowledge has affected their test performance, since it is acceptable to assume that expectations and motivational aspects change human behavior when subjects are informed about treatments or dosages.

Some studies examined hangover effects after drinking during daytime, without sleeping opportunities (Yesavage *et al*, 1994; Taylor *et al*, 1996). Results from these studies are difficult to interpret, since normally binge drinking takes place during the evening or night. Finally, in some studies participants received less than 6 h of sleeping time before next-morning tests started (Collins and Chiles, 1980; Collins, 1980). In these studies, the effects of sleep restriction probably interfere with the effects caused by binge drinking itself.

Taking into account the factors mentioned above, the present study examines the effects of alcohol hangover on memory functioning. To investigate if possible effects were caused by alcohol hangover-related sedation, a Mackworth clock test was also performed. This vigilance test measures readiness to react (ie vigilance) during prolonged visual search (Mackworth, 1948), and gives an insight into performance requiring arousal and sustained attention. Under these circumstances, it is hypothesized that alcohol hangover symptoms will significantly impair memory functioning.

METHODS

Subjects

Healthy volunteers were recruited by newspaper advertisement. Subjects were physically and mentally healthy, free from medication, and used no drugs of abuse. Written informed consent was obtained before the start of the study, and subjects were paid for their participation. All participants were treated in accordance with the guidelines for Good Clinical Practice and the Declaration of Helsinki. Subjects were moderate drinkers, consuming between 10 and 35 alcoholic beverages per week, and were experienced with binge drinking (drinking >5 alcoholic drinks on a single occasion). However, subjects were excluded if they had past or present alcohol or drug dependency (DSM IV, 1994). To be included, weight had to be within 20% of the normal range according to gender, height and stature, and a body mass index (BMI) below 28 kg/m^2. Also, caffeine consumption (<5 cups/day) and nicotine use (<10 cigarettes/day) were restricted, and if the experimenter or a subject suspected that the abstinence of coffee and cigarettes during the morning session would affect their test performance or behavior they were excluded from participation. Finally, Dutch had to be the native language of the participants.

Four subjects were excluded at screening, and replaced. Subjects were also replaced if they vomited within 1 h after treatment administration ($N=6$), or when they reported

sleeping less than 6 h ($N = 2$). A total of 48 subjects (24 men and 24 women) completed the study. The mean ± SEM age was 21.9 ± 2.5 years (men: 21.0 ± 1.7; women: 22.8 ± 3.0) and mean ± SEM weight was 68.3 ± 7.9 kg (men: 74.8 ± 9.8; women: 61.8 ± 6.0). The mean ± SEM number of alcoholic drinks/day was 3.42 ± 0.3 (placebo group: 3.0 ± 0.3; alcohol group: 3.8 ± 0.3), that is, approximately 24 standard alcoholic drinks per week (in the Netherlands a standardized alcoholic drink contains 12 g of alcohol).

Procedure

On each test session two subjects participated in the study. For the evening session, subjects were transported to the institute, and familiarized with the test procedures. Thereafter, a standardized dinner (macaroni) was served, followed by an evening session of all tests to establish baseline performance. During dinner and beverage consumption, subjects were seated in separate rooms in a relaxing atmosphere. Laboratory tests were performed in a soundproof and dimly illuminated test room. Subjects were then randomly assigned to either the alcohol group or the placebo group. Treatment of the alcohol group consisted of pure ethanol (1.4 g/kg body weight) mixed with orange juice (a total volume of 500 ml), representing the equivalence of 8–9 standard alcoholic drinks. The placebo group received 500 ml orange juice. Beverages were consumed in a gradual fashion, within 30 min, starting at 22.30 h (subject 1) or 23.00 h (subject 2). Subjects used a nose-clip while drinking and the beverages were flavored with Grand Marnier essence, both in order to blind treatment. In addition, up to 1 h after administration subjects of both groups performed breath alcohol tests approximately every 10 min. Subjects remained unaware of their BAC levels. Thereafter, subjects were transported home, and instructed to get a normal night rest (± 7 h of sleep). During the night, it was possible to consult the study physician and/or the experimental staff, if needed. The following morning the subjects were transported to the institute. Eating, smoking, and coffee drinking were not allowed. In addition, excessive water consumption was not allowed. BAC measurements were performed every 5–10 min. Tests started as soon as BAC was zero.

Subjective Assessments

Before the start of the morning session, the Sleep Quality Questionnaire (Mulder-Hajonides van der Meulen, 1981) was completed. The questionnaire contains 14 statements regarding sleep quality, and scores ranged from 0 (no sleeping problems) up to 14 (severely disturbed sleep). Also, total hours of sleeping and number of awakenings were recorded. In addition, alcohol-hangover related adverse events were reported, including sleepiness, drowsiness, concentration problems, headache, dizziness, lightheadedness, coordination problems, diplopia, palpitations, tinnitus, dry mouth, thirst, agitation, gastrointestinal disturbances, and nausea. From these data, hangover intensity, a composite score of the number of reported adverse events (moderate intensity = 1 point, severe intensity = 2 points), was computed. Finally, before and after the test battery, subjects rated their alertness on a 41-point equal interval scale, ranging from 'maximal alert' (41) to 'very sleepy' (0).

Test Performance

Word-learning test. The word-learning test (Dutch language version) is a computerized and standardized test with high internal consistency and high test–retest reliability. The test consists of 12 parallel lists of 15 monosyllabic meaningful nouns (immediate and delayed recall), complemented with 15 distracter words in the recognition test. During training, evening and morning sessions, different word lists were used. All presented stimuli are frequently used Dutch words, with high imageability (Loon-Vervoorn, 1985), and having low association with each other.

In all, 15 words were presented five times on a computer display. After each presentation, subjects had to write down as many words they could remember. The highest trial score was a measure of immediate recall. Then after 60 min, delayed recall was recorded. Finally, the original list along with 15 distracter words was presented. The subjects had to indicate by button-press whether a presented word was a member of the original list or not. Recognition was expressed in recognition time (ms) and recognition score (number of correct recognized words).

Mackworth clock test. Subjects were instructed to attend a running clock for 45 min, in which 12 dots were subsequently illuminated. Occasionally, nine times during the entire test, a dot was skipped from being illuminated, that is, the pointer made a 'double-jump', and subjects had to push a button as fast as possible. A response was considered as missing if the reaction time was longer than 1800 ms. The numbers of hits and false alarms were recorded.

Statistical Analyses

Statistical analyses were performed using the SPSS statistical program (SPSS 10.0, SPSS Inc., Chicago, IL, USA). The factors Group (two levels: alcohol group and placebo group), Time (two levels: baseline (evening) and morning session), OldNew (two levels: learned (old) and distracter (new) words) and Gender, and their interactions were tested for significance ($p < 0.05$) by using ANOVA for repeated measures. To examine the effects on learning, a separate analysis of immediate recall data was performed, which also included the factor Trial (five levels: trials 1–5). Additionally, analyses of the alertness scale included the factor Prepost (two levels: before and after the test battery).

RESULTS

BAC

Figure 1 shows that BAC increased rapidly after treatment administration and reached a peak BAC of 0.155% within 60 min after treatment consumption.

BAC reached zero approximately 10.5 h after treatment administration. Although not significant, alcohol elimination was faster in women (± 10 h) than in men (± 11 h).

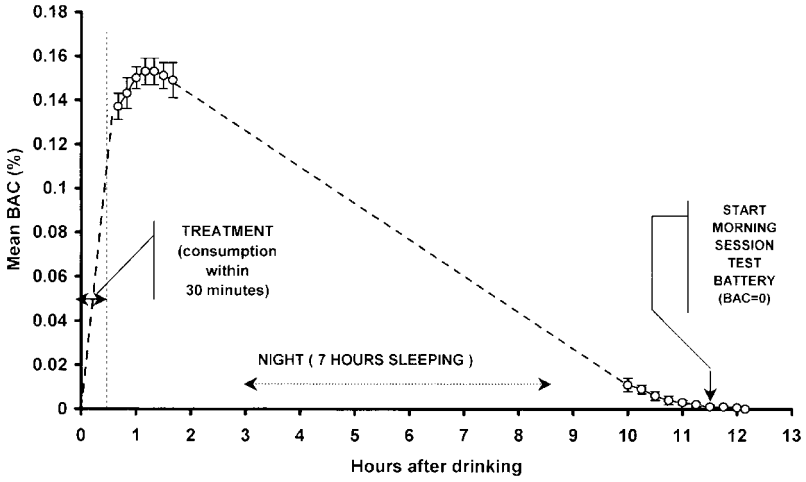

Figure 1 Mean BAC. Mean ± SE scores are presented.

Subjective Assessments

Sleep quality. All subjects slept approximately 7 h, without treatment-related awakenings (mean ± SEM number of awakenings: 0.8 ± 0.2 in the placebo group and 0.5 ± 0.2 in the alcohol group). Sleep quality scores did not differ significantly between the alcohol and placebo group. Sleep quality scores differed significantly ($F_{1,47} = 5.3$, $p < 0.03$) between women (score = 2.25) and men (score = 3.75). However, this difference has no clinical relevance, since both test scores indicate good sleep quality.

Hangover intensity. Relative to the placebo group, hangover intensity was significantly ($F_{1,44} = 23.2$, $p < 0.0001$) higher in the alcohol group. Also, the main effect of Gender was significant ($F_{1,44} = 7.4$, $p < 0.01$), reflecting that in the alcohol group the hangover intensity of women was significantly ($F_{1,22} = 5.8$, $p < 0.03$) higher than that of men. In contrast, this effect was not significant in the placebo group.

Alertness. The overall effect of Group was not significant ($F_{1,44} = 2.7$, $p < 0.1$). It is evident from Figure 2 that subjects were more alert during the morning session, when compared to evening baseline (Time: $F_{1,44} = 5.4$, $p < 0.03$). Also, the interaction between Time and Group was significant ($F_{1,44} = 24.7$, $p < 0.0001$). Relative to baseline, alertness in the morning session was significantly ($F_{1,22} = 27.8$, $p < 0.0001$) increased in the placebo group. In contrast, in the alcohol group, this effect did not reach significance ($F_{1,22} = 3.3$, $p < 0.08$). In the morning session, relative to the placebo group, subjective alertness was significantly reduced in the alcohol group before and after the tests ($F_{1,44} = 8.7$, $p < 0.005$; $F_{1,44} = 13.3$, $p < 0.001$, respectively). At baseline, alertness did not differ significantly between the two groups. Overall, women were less alert than men (Gender: $F_{1,44} = 5.4$, $p < 0.03$).

As expected, alertness decreased during performance of the laboratory test battery (Prepost: $F_{1,44} = 59.1$, $p < 0.0001$). The interaction between Time and Prepost was also significant ($F_{1,44} = 4.7$, $p < 0.04$), indicating that the decrease in alertness was of greater magnitude at baseline than in the morning session. The interaction between Prepost, Gender, and Group was also significant ($F_{1,44} = 6.6$, $p < 0.02$), indicating that the Prepost reduction in alertness is greater in women in the alcohol group, whereas the Prepost difference in alertness in the placebo group is greater among men.

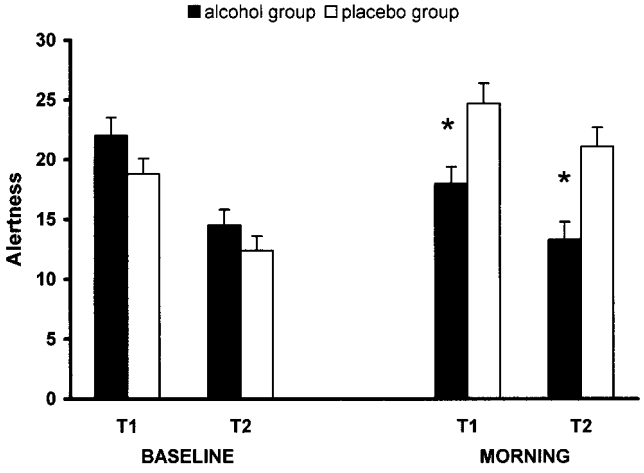

Figure 2 Alertness. Mean ± SE scores from the visual analog scale assessing alertness, reported at baseline and the morning session, both before (T1) and after performance of the test battery (T2). Significant differences ($p < 0.05$) between the alcohol and placebo groups are indicated by *.

Test Performance

Table 1 presents mean ± SEM scores on the tests of the evening session (baseline performance) and the morning session, and the outcome from the statistical analyses, both *within* and *between* the alcohol group and the placebo group. All 48 subjects completed the Mackworth clock test. Due to technical problems, the word-learning test data of two subjects was lost and not included in the statistical analyses.

Word-learning test. Results from the word-learning test are shown in Figure 3 and Table 2.

Immediate recall: The effects and their interactions for immediate recall (highest trial score) were not significant.

Learning: Statistical analyses revealed a significant overall learning effect (Trials: $F_{4,39} = 170.5$, $p < 0.0001$). The overall effects of Group, Gender, and Time were not significant ($F < 1$).

The interactions between the factors Trial, Time, Group, and Gender were not significant, except for the interaction between Trials, Time, and Group ($F_{4,39} = 4.0$, $p < 0.01$).

Further analysis showed that in Trial 4 of the morning session of the alcohol group immediate recall was significantly ($F_{1,42} = 7.9$, $p < 0.01$) lower than in trial 4 of the placebo group. However, as is evident from Table 2, the clinical relevance of this finding is questionable, since after completion of the learning sessions (trial 5), as well as all previous sessions during the learning process (first trial score, trial 2 and trial 3), the differences between the conditions are very small and not significant.

Delayed recall: ANOVA revealed a trend towards significance ($F_{1,42} = 3.4$, $p < 0.07$) for the effect of Group. The effect of Time was significant ($F_{1,42} = 27.3$, $p < 0.0001$), as well as the interaction between Group and Time ($F_{1,42} = 7.0$, $p < 0.01$). Further analysis showed that, relative to baseline, in the morning session delayed recall was significantly poorer in both the placebo ($F_{1,22} = 5.3$, $p < 0.03$) and the alcohol group ($F_{1,20} = 21.5$, $p < 0.0001$). However, in the morning session, delayed recall of the alcohol group was significantly ($F_{1,44} = 6.0$, $p < 0.02$) poorer when compared to the placebo group. The other effects and their interactions were not significant.

Recognition score: The overall effects of Group, Time, and Gender were not significant. A significant ($F_{1,42} = 10.2$, $p < 0.003$) effect of OldNew was found, indicating that distracter words (New, 14.2 ± 0.10 words) were more easily recognized than learned words (Old, 14.6 ± 0.07 words). The interaction between Time and OldNew was also significant ($F_{1,42} = 7.8$, $p < 0.008$), indicating that the difference in recognized learned and distracter words was greater during the morning session ($\Delta = 0.7$ words) when

Table 1 Performance During Baseline and Morning Session

	Placebo group		Alcohol group	
	Baseline	**Morning**	**Baseline**	**Morning**
Mackworth clock test				
Number of hits	7.3 ± 0.4	6.9 ± 0.3	7.5 ± 0.3	6.1 ± 0.5
False alarms	3.2 ± 0.7	4.8 ± 1.0b	4.1 ± 0.9	3.6 ± 0.8
Word-learning test				
Immediate recall	13.5 ± 0.3	13.6 ± 0.3	13.5 ± 0.2	13.1 ± 0.4
Delayed recall	12.3 ± 0.4	11.5 ± 0.5[b]	12.0 ± 0.5	9.4 ± 0.7[b,p]
Recognition score old	14.5 ± 0.1	14.0 ± 0.2[b]	14.3 ± 0.2	13.8 ± 0.2[b]
Recognition score new	14.4 ± 0.2	14.5 ± 0.1	14.6 ± 0.2	14.7 ± 0.1
Recognition time old	650 ± 20	692 ± 23[b]	703 ± 38	766 ± 36[b]
Recognition time new	689 ± 26	688 ± 25	715 ± 27	724 ± 27

Mean ± SE scores are presented. Significant differences ($p < 0.05$) from placebo or baseline are indicated by p and b, respectively. Old = learned words, New = distracter words.

Table 2 Learning Ability Mean ± SE Correct Recalled Words (Immediate Word Recall) are Shown

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Evening					
Placebo	7.5 ± 0.4	10.2 ± 0.4	11.8 ± 0.4	12.5 ± 0.3	13.1 ± 0.3
Alcohol	6.7 ± 0.3	9.4 ± 0.5	11.6 ± 0.4	12.6 ± 0.4	13.1 ± 0.3
Morning					
Placebo	7.0 ± 0.4	10.0 ± 0.4	11.4 ± 0.5	12.8 ± 0.3	13.0 ± 0.4
Alcohol	7.2 ± 0.4	10.0 ± 0.4	11.5 ± 0.4	11.6 ± 0.4	12.9 ± 0.4

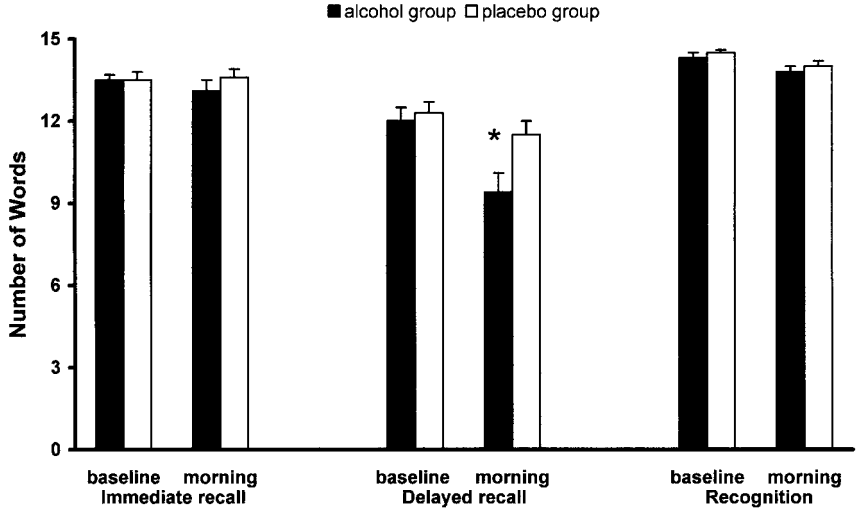

Figure 3 Word-learning test. Mean (+SE) number of words recalled (immediate and delayed recall) and recognized out of the 15 learned words. Significant differences ($p < 0.05$) from placebo are indicated by *.

compared to the evening session ($\Delta = 0.1$ words). Other interactions were not significant.

Recognition time: The overall effects of Group, Gender, and OldNew were not significant. However, a significant ($F_{1,42} = 7.7$, $p < 0.008$) overall effect of Time was found. The interaction between Time and OldNew was also significant ($F_{1,42} = 10.5$, $p < 0.002$), indicating that relative to the distracter words, learned (Old) words were recognized faster in the evening session (−26 ms) but slower in the morning session (+23 ms). The other interactions were not significant.

Mackworth clock test

Number of hits: The effect of Group was not significant. ANOVA revealed a significant ($F_{1,44} = 7.7$, $p < 0.01$) effect of Time, indicating that performance in the morning session was worse when compared to baseline. The interaction between Time and Group was not significant ($F_{1,44} = 2.9$, $p < 0.10$).

False alarms: The effects of Group and Time were not significant. However, the interaction between Group and Time was significant ($F_{1,44} = 5.0$, $p < 0.03$). Relative to baseline, in the morning session the number of false alarms was significantly ($F_{1,22} = 4.8$, $p < 0.04$) increased in the placebo group, whereas the number of false alarms in the alcohol group was nonsignificantly decreased. The number of false alarms in the morning session did not differ significantly between the two groups.

DISCUSSION

Memory Functioning and Vigilance Test Performance

At baseline, the alcohol and the placebo group did not significantly differ on any memory test parameter, indicating that the groups matched well. In the morning session, however, delayed recall differed significantly *between* the two groups. In contrast, no significant impairment was observed for immediate recall and recognition parameters, indicating that encoding and consolidation processes seem to be intact. The specific finding of impaired delayed recall, however, indicates that retrieval processes were impaired during alcohol hangover. Nevertheless, retrieval was unaffected in the recognition test, which is understandable, since retrieval is much easier in the recognition test (cued recall) than during (free) delayed recall. That is, during delayed recall the subjects are required to explicitly write down the words, whereas in the recognition test they must simply identify which words (from a larger group of words) were presented on the original list. Finally, the present results are in line with those of other alcohol hangover studies that failed to find significant impairment on tests measuring immediate free recall (Chait and Perry, 1994) and probed memory recall (Finnigan *et al*, 1998).

In contrast to memory functioning, vigilance performance was not significantly affected during alcohol hangover. In line with a previous study that also applied the Mackworth clock test (Lemon *et al*, 1993), the difference *between* the two groups was not significant in the morning session.

Subjective Assessments

Figure 2 illustrates that alertness in the placebo condition was significantly increased in the morning session. This finding is consistent with other studies revealing that alertness is maximal after awakening and gradually decreases as the day continues (Monk *et al*, 1989; Johnson *et al*, 1992). In contrast, performance measures were generally worse in the morning session, when compared to baseline. Increased alertness possibly weakened the expected effects of alcohol hangover on the Mackworth clock test in the alcohol group, indicated by the nonsignificantly decreased number of hits and nonsignificantly increased number of false alarms in the morning session.

The number of hangover symptoms varied between the participants, but none of the subjects of the alcohol group reported the absence of hangover-related adverse events. Also, women reported a significantly greater number of adverse events than men. Further, in line with previous studies (Sutker *et al*, 1983; Mishra *et al*, 1989; Mumenthaler *et al*, 1999), women eliminated ethanol faster from the blood than men, corresponding to gender differences in bodily fat/water ratio. It was unlikely that this would evoke gender differences on test performance, since the difference in elimination time was not significant and tests started only when BAC was zero.

In contrast to the subjective assessments, no significant gender differences were found on objective performance parameters. Other researchers also reported that hangover intensity and number of adverse events do not correlate well with performance impairment during hangover (Seppälä *et al*, 1976; Laurell and Törnros, 1983; Chait and Perry, 1994).

Concluding Comments

The results clearly show the specific effects of alcohol hangover on explicit memory, which cannot be explained by increased sedation, since vigilance performance on the Mackworth clock test was not significantly impaired. The impairing effects on memory retrieval processes are in line with those observed after acute alcohol intoxication and those found in alcoholics. Unfortunately, alcohol hangover effects are not always taken seriously. Our results show that there are reasons to change this opinion.

ACKNOWLEDGEMENTS

This research was supported by internal funds only.

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