INTRODUCTION

Early studies on the effects of alcohol on the sober social drinker have yielded inconsistent results. Frequency (Bergman, 1985) and quantity (McVane Butters et al., 1982) of alcohol consumption have been implicated as contributing factors in the manifestation of any deleterious effects in sober cognitive performance. Williams and Skinner (1990) found performance deficits in heavy social drinkers (>500 g/week). Similarly, Waugh et al. (1989) indicated that quantity per occasion showed no relationship with test scores in the sample of light (<40 g/day) and moderate (41–80 g/day) drinkers, but the performance of heavy drinkers (>80 g/day) was significantly lower in tests of free recall and maze learning.

Stemming from the ‘8 h bottle to the throttle’ rule, aviation studies have looked at the direct ‘morning after’ effects of alcohol. Research in this area has revealed that impairments due to moderate levels of alcohol consumption may persist throughout the night to the morning after (Yesavage and Leirer, 1986). Myrstein et al. (1980) found that psychomotor performance dropped by 15% in the severe hangover group compared to a drop of 1% in the mild hangover group. The cognitive tasks (mental arithmetic task, Bourdon test, coding test and memory task) deteriorated by 23% for the severe hangover group and by 8% for the mild hangover group.

Studies have looked at the direct morning-after effects of alcohol have employed the pharmacological model of drug action. Consequently, through consideration of the biochemical effects of alcohol, the investigator determines the quantity of alcohol and the speed of drinking. This approach is limited in a number of ways. It is recognized that a large proportion of people exceed the recommended guidelines of a safe level of alcohol consumption, 21 units/week for men and 14 units/week for women (File et al., 1990). It is common in past research to administer drinks containing up to 1 g/kg of alcohol (Roehrs et al., 1991; Lemon et al., 1993). This approach fails to take into consideration the usual amount of alcohol consumed. Finigan et al. (1998) found no deleterious effects the morning after alcohol consumption in their sample of social drinkers. It was revealed that 67% of the sample consumed more than 21 units on any one drinking occasion. It was also observed that 80% of the participants who considered themselves social drinkers reported consuming over 7 units of alcohol during normal drinking occasions. Thus the tolerance level of this sample of heavy drinkers may have obscured any deleterious effects of the administered dose of 7 units. Tian and McDonald Young (1986) administered a dose of 1.00 ml/kg ethanol and observed that light social drinkers, for which the administered dose was significantly greater than their usual consumption level, were consistently the most impaired in relation to the control condition and the moderate and heavy drinkers. In order to investigate the influence of alcohol-induced hangover pertaining to individuals, an account must be made of the usual amount of alcohol consumed per occasion.

The natural drinking environment is saturated with social meaning, yet in laboratory studies the company has been imposed. The social excitatory aspect of consuming an alcoholic beverage of choice in chosen company has never been investigated. Few studies have considered the importance of the drinking environment. Collins and Chiles (1980) partly addressed this issue and tried to create a party atmosphere by allowing participants to play ping pong, cards, and table hockey. Myrstein et al. (1980) also reported an attempt to create a relaxed social atmosphere by letting the research team join the participants during the experimental meal.

On consideration of the limitations of past research, the present investigation placed great emphasis on ecological validity. Thus participants consumed their usual quantity of
alcohol in the place and company of choice. The rate of consumption and type of beverage were not imposed by experimental procedure.

The present research aims to investigate the naturally occurring next-day effects of alcohol consumption, employing sophisticated laboratory measures rather than scores from educational assessments. The next-day effects were investigated at three time points: 09:00, 11:00 and 13:00 hours. This facilitated an investigation of the time course of any post-intoxication effects. Memory and psychomotor tasks have shown specific diurnal effects in that there is superior short-term memory in the morning, which deteriorates over the day and slower RT in the morning, which speeds during the course of the day (D’Reaux et al., 2000). The present research aims to investigate whether or not the next day effects of drinking moderate diurnal effects on performance.

MATERIALS AND METHODS

The participants were 48 students of the University of Ulster (15 men, 33 women) whose mean age was 23.38 (SD 5.26, range 18–43) years.

Participants were given written and verbal information about the study, following which they signed consent. The night before the hangover testing session, participants were requested to consume alcohol only between 22:00 and 02:00 hours and to refrain from eating any food after the drinking session. Participants were requested to abstain from alcohol for 24 h immediately before the no hangover testing session. Breakfast was eaten at 08:00 hours before each test session and participants were asked to abstain from drinking any caffeine drinks after breakfast.

Design

The study followed a repeated measures design with time of day (09:00, 11:00 and 13:00 hours) and order of testing (hangover/no hangover; no hangover/hangover) as between-participant factors. Each participant carried out tasks in both hangover and no hangover state and the two sessions were approximately 1 week apart. The counterbalanced repeated measures design used a naturalistic drinking environment to facilitate the investigation of participants’ usual volume of consumption of preferred beverage in chosen company. Participants were randomly allocated to an order and time of testing. The randomization procedure ran in eight cycles with six participants randomly allocated to a time and order within each cycle.

Procedure

Participants confirmed compliance with the pretesting requirements. Following this, participants blood alcohol levels were recorded using a Lion Alcolmeter. The participants completed questionnaires on demographic information, drinking practices, hangover signs and symptoms, and sleep quality and quantity. Questionnaires assessing mood (Herbert et al., 1976), anxiety (Spielberger et al., 1970), perceived stress (Cohen et al., 1983) and cognitive interference (CIQ; Sarason, 1978) were completed (these results will be presented elsewhere). Following this the task battery of objective tasks was administered in a standard order (free recall; regular reaction time; selective attention; divided attention; Stroop test (A complex information processing task in which participants are required to process information under conditions of distraction); irregular reaction time; spatial attention; sustained attention; five-choice reaction time; delayed recognition). A short practice trial preceded each computer-based task.

Tasks

The free recall task consisted of 20 words presented in uppercase letters on the centre of the screen at a rate of 1 word every 2 s. The participants were instructed to remember as many words as possible, and told that order was not important. Immediately after the last word was presented ‘THE END’ appeared on the screen. This was the cue for the participants to begin writing down the recalled words. The participants were given different word lists on each testing occasion. The recognition components of the memory task were administered approximately 60 min after immediate recall. For the delayed recognition, the participants were given a list of 40 words, consisting of the 20 free-recall list, previously presented among 20 distracters. Each participant was instructed to circle any word they recognized from the target list presented at the start of the experimental session.

Two simple reaction-time (RT) tasks and a five-choice reaction time task were administered. For the simple reaction-time tasks an empty square was positioned in the centre of the screen. At predetermined times an ‘X’ appeared inside the square. The participant was required to respond as quickly as possible with a space bar press when this appeared. One block of five trials was presented and in the regular condition the 10 events in each trial had a constant inter-stimulus interval of 2000 ms. In the irregular condition, five blocks of 10 trials were presented. The inter-stimulus intervals had increments of 500 ms within the range 500–5000 ms. The 10 different inter-stimulus intervals were equally represented and randomized within each block.

For the five choice reaction time task the stimulus display consisted of five light-emitting diodes (LEDs) with a corresponding touch-sensitive keypad mounted on a black angled panel 30° to the vertical. The LEDs were positioned in an arc around a centrally positioned touch-sensitive keypad. The separation between each light was 30° and the distance between each light and the central resting position was 15 cm. The participants were required to hold the stylus on the centre keypad and respond to an illuminated light by moving the stylus to make contact with the appropriate keypad and then return it to the centre position. This had the effect of extinguishing the light and simultaneously switching on another, which again was responded to, and so the cycle continued. The bulbs lit in an order with the stipulation that each bulb was equally represented in the sequence. The times to move from the centre keypad to the stimulus keypad (initial move time) and to return to the centre position (return time) were recorded.

Analysis

Two separate multivariate analyses of variance were performed on demographic and alcohol consumption variables, with both sex and time of testing as between-participant factors.

RESULTS

Subjects defined themselves as social drinkers, and all blood alcohol levels were zero the morning after alcohol
consumption in all but two subjects, who had low readings of 5 mg/100 ml. Men reported consuming on average 10.23 ± 3.76 (mean ± SD) units and women reported consuming 10.55 ± 7.14 units of alcohol per drinking occasion (1 unit was defined as one glass of wine, one measure of spirits or a half-pint of beer; equivalent to about 9 g ethanol). 77% consumed more than seven units the night before testing and 60% reported drinking more that 21 units (men) and 14 units (women) in any 1 week.

Table 1 shows the participants’ drinking history and their consumption on the evening before the ‘hangover’ testing, which was greater in men (14.70 ± 8.432 units) than in women (10.54 ± 7.139 units). When the means of the measures shown in Table 1 were compared according to the time of testing to which the subjects had been allocated, no statistically significant differences were found.

**Free recall task**

The performance measure in the free recall task corresponds to the number of words correctly recalled, in any order, from a list of 20 target words. The three-factor ANOVA revealed no main effects. However, the first-order interaction, of state × time ($F[2,42] = 4.54; P < 0.05$) revealed significance and the second-order interaction, order × time × state ($F[2,42] = 3.42; P < 0.05$) reached significance.

Subsequent analysis indicated significantly more words were recalled in the no hangover (10.18 ± 2.04) condition than in the hangover (8.25 ± 1.81) condition at the 09:00 hours testing session ($t[15] = -3.081; P < 0.01$). Throughout the morning testing sessions the mean number of words recalled in the hangover condition increased from a low of 8.25 words at 09:00 to 9.5 words at 13:00 hours. In contrast, the number of words recalled in the no hangover session decreased from 10.18 at 09:00 to 9.00 at the 13:00 hours testing session.

With respect to the second-order interaction of order × time × state split-plot analyses (state × time) were performed on each order of testing. The two-factor 2(state) × 3(time) ANOVA for order 1 revealed no main effects; however, the interaction of state × time approached significance ($F[2,21] = 3.34; P = 0.055$). The two-factor 2(state) × 3(time) ANOVA performed on order 2 again failed to reveal any main effects, but a significant interaction of state × time ($F[2,21] = 4.52; P < 0.05$) was observed. Further analyses revealed a significant difference between hangover and no hangover at time two ($t[8] = -2.81; P < 0.05$) indicating greater recall of words in the no hangover (9.87 ± 1.95) condition than in the hangover (8.37 ± 1.30) condition. However, this result must be treated with caution as with the application of the Bonferroni correction this result failed to reach significance.

**Delayed recognition task**

The three-factor ANOVA performed on the number of words recognized after a 60 min delay revealed a main effect of state ($F[1,42] = 6.10; P < 0.05$), in that less words were recognized in the hangover condition (12.5 ± 3.12) than in the no hangover condition (13.4 ± 3.10).

**Simple reaction time tasks**

The results of the ANOVA performed on the reaction time data for the task with a regular interstimulus interval showed a significant main effect of state ($F[1,41] = 9.99; P < 0.05$). This result indicates that reaction times in the hangover condition (311.95 ± 82.69) were significantly longer than in the no hangover condition (274.25 ± 49.74).

The ANOVA performed on the individual standard deviations revealed no difference between hangover and no hangover, indicating that the observed differences on reaction time between hangover and no hangover is not attributable to differences in variability of reaction times within the task duration.

A similar result was obtained from analyses of irregular interstimulus interval reaction time. There was a significant main effect of state ($F[1,42] = 10.47; P < 0.05$), indicating that the reaction times in the hangover condition (371.19 ± 78.78 ms) were significantly slower than in the no hangover condition (337.83 ± 41.13 ms). The analyses of standard deviations of reaction times during the task for each condition revealed no significant differences. Thus the observed difference in reaction time is not due to increased variability or an increase in gaps or uncharacteristically long response times.

**Five choice reaction time task**

Separate analyses were conducted on the move time (the time to respond to an illuminated light, to move to the stylus, and to move the stylus to the target keypad), the return time (the time to return to central position), and the decision time (the move time minus the return time).

**Initial move time.** The analysis of the initial move time revealed no main effects; however, the first-order interaction of order × state reached significance. This interaction (see Fig. 1) indicates that the significantly ($F[1,34] = 4.39; P < 0.001$) slower move time in the hangover state (738.4 ± 116.67 ms) compared to the no hangover state (675.97 ± 88.41 ms) depends on order of testing. That is, the difference is only

| Age when had first drink | 24.5 (6.34) | 22.97 (4.64) |
| Age when first drink | 16.55 (1.59) | 15.26 (1.41) |
| Usual units per occasion | 10.23 (3.76) | 10.55 (7.14) |
|Usual units per week | 23.9 (11.82) | 24.03 (10.5) |
| Units evening before test | 14.70 (8.43) | 10.41 (7.07) |

Results shown as mean (SD).
This is similar to the age of participants in the studies of Finigan et al. (1998) (mean age 25.6 years) and Smith et al. (1995) (mean age 21.2 years). The incidence of exceeding the recommended weekly limit of alcohol consumption was 67.5% in the study of Finigan et al. (1998) and 66% in our sample.

Differences in alcohol consumption between the sexes, with men having higher levels of consumption than women, have remained constant across societies (Neve et al., 1996; Wilsnack et al., 2000). The present research also revealed that men reported the consumption of more alcohol than did women, the night before the hangover test session. However, the present investigation revealed similar reports of usual quantity per occasion for men and women. This supports the evidence of recent increases in women’s consumption relative to men in some European countries (Simpura and Karlsson, 2001).

Hangover did not affect the average number of words recalled. However, the present study revealed poorer free recall performance the morning after alcohol consumption at the 09:00 hours test, which is the time when memory performance benefits from the diurnal superiority seen in the no hangover condition. The interaction effect shows that free recall performance during hangover improves to a level comparable with the no hangover condition by 13:00 hours. This improvement in memory performance was not observed in the delayed recognition task. The present study found that fewer words were recognized, after a 60 min delay, the morning after alcohol consumption than the morning after no alcohol consumption. This suggests that different cognitive functions are differentially affected during alcohol-induced hangover. This study does not directly address the issue of encoding. Impaired recall in the immediate and delayed conditions could be due to impairments in the initial encoding of the stimuli/impairments in the initial retrieval processes. The study does, however, differentiate between active retrieval (recall) and familiarity (recognition). Whereas recognition involves selection of the correct response from a number of alternatives, recall requires active retrieval of the correct response from memory. The data suggest both of these processes are impaired the morning after alcohol consumption. However, the recovery of function observed throughout the morning in the recall task was not evident in the recognition task.

The reaction time tasks employed in the present investigation were employed by Smith et al. (1995) and are sensitive to changes in state (e.g. working at night; Smith and Miles, 1985). Smith et al. (1995) revealed decreased reaction time in the variable inter-stimulus reaction time task, in their high alcohol, high negative life events group. However, Smith et al. did not assess the morning-after effects of alcohol but rather the residual effects of drinking on the weeks leading up to testing. Thus the regular interstimulus task was insensitive to the effects of residual alcohol but proved sensitive to the effects the morning after a normal night’s drinking.

Choice reaction time tasks are similar to simple reaction time tasks except that participants have to make one of a fixed set of responses, depending on which of a small, fixed set of stimuli occurs. Thus both thinking time and moving time are usually longer than in simple reaction time tasks. The five-choice reaction time task revealed a slower response time to return to the central position when in the hangover state. This is in accordance with the observed effect of the post-intoxication state on the simple reaction time tasks. In relation

**DISCUSSION**

The participants in the present study had a mean age of 23.4 years. This is similar to the age of participants in the studies of
to the initial move time and the decision time, the order of testing impacts on response speed. When participants were tested in the no hangover session second, a faster response time was observed, suggesting that participants can take advantage of previous practice when in the no hangover state but not when in the hangover state.

The primary aim of this paper was to investigate the effects of alcohol-induced hangover on memory and simple psychomotor performance. The results from the analysis of the drinking level data showed that this sample of social drinkers consumed levels of alcohol equivalent to the level of alcohol consumption observed in past research (Smith, 1995; Finnigan et al., 1998). It also indicated a high proportion of social drinkers exceeding the recommended weekly limits. It is apparent from the results from memory and psychomotor task that these individuals are performing at a lower level the morning after alcohol consumption (hangover state) compared to the morning after no alcohol consumption. Tasks that measure fine motor performance revealed slower response times when in the hangover state, which is in line with the findings of Myrstein et al. (1980). Furthermore, performance on the memory tasks would suggest that, even when the information is stored, the consumption of alcohol the night before prohibits this information from being available over the filled 60 min delay interval.

REFERENCES


