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ORIGINAL INVESTIGATION

T. Duka · R. Weissenborn · Z. Dienes

State-dependent effects of alcohol on recollective experience, familiarity and awareness of memories

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Abstract *Rationale:* Explicit memory (EM) is the memory for events which occurs with full awareness of where and how the recalled events took place, whereas implicit memory (IM) is the memory which is unfolded without any awareness of these events and usually becomes apparent when performance is facilitated by its presence. These two types of memory can be understood as different systems. Findings attempting to differentiate between the two systems in normal subjects have been controversial, with some researchers arguing that there is a single memory system and only the match in processes used during learning and later at retrieval can be important. *Objectives:* The present study compared the effects of alcohol (0.8 g/kg) or placebo administered prior to encoding and/or retrieval on measures of explicit and implicit memory in terms of recollective experience and familiarity. *Methods:* At encoding subjects studied a list of 80 words presented in pairs. At retrieval, participants first carried out an implicit stem completion task, followed by an explicitly cued recall task (stem completion) which measured IM and EM respectively. After stem completion participants were required to indicate whether the items from the studied list were consciously recollected ("remember" response) or was known for a fact that were presented in the studied list ("know" response). In the IM task completed items from the studied list but not recognised by the subjects as such indicated memory without awareness. Studied items were of high and low associations. Forty-eight participants were tested in one of four drug conditions: alcohol-alcohol, placebo-placebo, placebo-alcohol, alcohol-placebo. *Results:* In the implicit stem completion task, alcohol did not affect overall correct completion rates. However, participants who received alcohol prior to encoding reported lower awareness of correctly completed study items. In the cued recall task, alcohol also did not affect overall performance. However, participants in the same drug-state conditions (SS) reported greater recollection than familiarity with study material, whereas participants who encoded and retrieved material in different drug-state conditions (DS) reported recollection and familiarity to the same extent. In addition, DS participants showed more familiarity with study material compared to SS participants. Direct comparisons between IM and EM tasks demonstrated that alcohol at retrieval decreased the cued recall of items from high associations compared to placebo, but did not have any effect on implicit stem completion. *Conclusions:* In summary, these results demonstrate a dissociation of alcohol effects on measures of EM and IM. Alcohol administered prior to encoding reduced awareness of implicitly retrieved material, but did not impair IM per se, confirming previous findings with alcohol. In addition, the data provided new evidence for state-dependent retrieval effects on EM but not IM. It was also shown that for explicitly retrieved items, recollective experience benefits from same drug state, whereas familiarity benefits from different drug state between encoding and retrieval.

Keywords Implicit memory · Explicit memory · Encoding · Retrieval · High association · Low association · Drug-state

T. Duka (✉) · R. Weissenborn · Z. Dienes
Laboratory of Experimental Psychology, University of Sussex, Falmer, Brighton BN1 9QG, UK
e-mail: dorad@biols.susx.ac.uk
Tel.: +44-1273-678879, Fax: +44-1273-678611

Introduction

Implicit memory has been contrasted to explicit memory as referring to expressions of memory that do not require the person to be aware of the memory as a memory; instead they simply give rise to facilitation on tasks that do not refer to the previous study episodes (Schacter 1987; Kirsner 1998). Findings that implicit and explicit memory are selectively impaired in amnesic patients (Shimamura 1986, for review) have directed interest in dissociating these two types of memory. In several studies involving normal subjects, manipulations of levels of processing, stimuli modalities, retention intervals, and interference have led to a distinction between these two kinds of memory (for review, Schacter 1987). Two broad competing theoretical perspectives have emerged to account for the dissociations in these studies: The “process” theory arguing for different processes or operations within a single unitary memory system (Roediger et al. 1989); and the proposal of different “memory systems” (Tulving and Schacter 1990). The systems approach implies the involvement of two separate neuronal substrates. This proposal is supported by data obtained with amnesic patients or patients with Korsakoff syndrome who are capable of learning skills or remembering procedures despite being severely impaired in their ability to process episodic memories (Shimamura 1986; Lister et al. 1991; Brunfaut and d’Ydewalle 1996). Psychopharmacological studies with the two drug classes, cholinergic antagonists and GABAergic agonists, have further supported this view although not conclusively (for review, see Duka et al. 1996). In several studies, it was shown that whereas scopolamine (a cholinergic antagonist) impaired explicit but left implicit memory unaffected (Nissen et al. 1987; Kopelman and Corn 1988), a benzodiazepine (GABAergic agonist, lorazepam, and more recently with midazolam) was shown to impair explicit and implicit memory (Sellal et al. 1992; Hirshman et al. 1999). However, several benzodiazepines impaired only explicit memory, leaving implicit memory unaffected (Danion et al. 1989, 1990). Attention should be drawn, however, to problems with some of these studies. Most studies did not match level of difficulty of implicit and explicit tasks or use experimental manipulations to ensure that the implicit task was not contaminated by explicit retrieval.

Extensive research has been carried out concerning the effects of alcohol on cognitive functions, such as learning and remembering information presented at time of intoxication, however, mostly on aspects of explicit memory. This detrimental effect of the presence of ethanol in the bloodstream on subsequent learning episodes is well documented in the literature, particularly when acute doses of alcohol are involved (e.g. Jones 1973; Birnbaum et al. 1978; Hashtroudi et al. 1984). Alcohol can have a severe disruptive influence on human memory, sometimes even inducing amnesic instances, the extent to which depends on the blood alcohol level (Parker 1984). Such psychopharmacological studies have also provided evidence for the differentiated nature of the human memory system. For example, some experiments have focused on specifying which components of the memory processes are affected, such as encoding (i.e. formation of an event representation), consolidation (the translation of encodings into a stable lasting form) or retrieval (the recovering of the representation under certain conditions). Parker et al. (1981), concluded that alcohol primarily impairs the process of encoding target material. Concerning differential effects of alcohol on explicit versus implicit aspects of memory, there is some evidence of better implicit retrieval under the influence of alcohol than explicit retrieval (e.g. Hashtroudi et al. 1984). Thus little is known about the effects of alcohol on implicit memory. The present study sought to investigate further the effect of alcohol on implicit versus explicit aspects of memory.

Tests of implicit and explicit memory were matched for the cues given at retrieval and also the “remember”/“know” responses procedure was used to help classify different types of memory. A “remember” response indicates that recognition of an item is accompanied by some conscious recollection of its prior occurrence, whereas a “know” response indicates no conscious recollection of its prior occurrence. Thus, a “know” response, while given on objectively an explicit memory task, may be partly based on implicit processes (Gardiner and Java 1990; Java 1994). Although a “remember” response does not rule out that it could in addition be an implicit memory for the item, it does establish the presence of explicit memory. Interpretation of “remember” and “know” responses remains controversial. Donaldson (1996) and Hirshman and Masters (1997) argue that many of the dissociations between “remember” and “know” may be reducible to two-criterion STD. However, neither of these papers actually argues that the distinction between “remember” and “know” states of awareness should be dropped. On the contrary, both papers endorse the reality of the distinction; they simply call into question some of the evidence for it, while approving of other evidence.

Explicit and implicit retrieval can be facilitated by the presence of context (Tulving 1982, 1983; Schacter 1987). Contextual cues associated either with the meaning of the stimulus included in the information or with the situation in which that information was originally acquired facilitate retrieval. Godden and Baddeley (1985) referred to these two conditions as interactive (more related to the meaning of the stimuli) and independent (more related to the environment) context. The relationships between interactive and independent context and implicit and explicit memory have not been previously systematically explored, but the following observations are consistent with existent data. In terms of explicit memory, cued recall or recognition appears to be affected by interactive context but not normally by independent context. On the other hand, implicit memory is consistently affected by independent context like modality of presentation. Interactive context can have an effect on implicit memory tasks under some conditions, but the effect is less than on explicit memory (Graf and Schacter 1985). Generally it seems likely that different systems underlie performance in implicit tasks that involve different domains.

The use of a drug as a cue has been explored in animals and in humans in the case of recall, cued recall and recognition measurements of explicit memory (Eich 1980) but we know of only one report in the literature (Polster et al. 1993) about a study in which the effects of midazolam as a drug cue were tested on an implicit task (perceptual facilitation in identifying degraded pictures and words) and no evidence for a state dependent effect was given. With very few exceptions, unsuccessful reports on state dependency on explicit retrieval have been derived from studies in which interactive contextual cues were introduced during retrieval (Eich 1980).

In a recent study (Weissenborn and Duka 2000), we investigated the effect of alcohol in the dose of 0.8 g/kg on explicit memory measures of free recall under drug-state conditions by varying interactive context in form of semantic associations. High and low association pairs of words were used to induce varying strength of interactive context. We demonstrated, in accordance with the Search Association Model (SAM) of memory (Clark 1995), a limited capacity of available cues in assisting recall. Thus, although total recall was not facilitated as such in the presence of drug as a contextual cue, there was an increased likelihood to recall high associations compared to low associations. These data suggested that alcohol as a drug may provide an internal or independent context, albeit weak, to assist additional cues provided by the semantic associations. The cue provided by alcohol may have been especially weak under recall, which depends on recollective retrieval and employs strategies dependent on salient cues (in this case the high associations).

In the current experiment, high and low semantic association pairs of words balanced for semantic frequency, imagery and length of syllables were presented and were used to vary interactive context. A traditional state-dependent retrieval design was employed where half of the participants studied the items under alcohol, half under placebo followed by retrieval of the items under alcohol or placebo, giving four groups (alcohol-alcohol, alcohol-placebo, placebo-placebo, placebo-alcohol). Explicit memory was tested by a cued stem completion task, whereas implicit memory by implicit stem completion. In the former, the participants had to use the study items to complete the stems in the latter participants had to complete the stem with the first word that came to mind. As discussed above implicit and explicit memory tasks were verified for recollection and familiarity of memories by introducing remember and know responses (Java 1994). Thus the present study sought to examine the effects of alcohol at encoding and/or retrieval of high versus low association paired items on measurements of EM using recollective experience and familiarity responses, and of IM focusing on awareness of memories. Based on the above observations and on the data from the literature on how implicit memory may be affected by context (Schacter 1987), we postulated that familiarity responses rather than recollective responses would be more susceptible to less salient cues as in the case of a drug-state. Concerning the effects of alcohol we predicted that alcohol would impair explicit but not implicit aspects of memory.

Materials and methods

Participants

Twenty-four male and twenty-four female paid participants were recruited from the student population at the University of Sussex. Participants were aged 18–34 years (mean=22.0, SEM=0.46) and native English speakers. Self-reported alcohol intake ranged from 2 to 40 units/week (mean=13.02, SEM=1.52). An alcohol unit refers to a glass of wine, half a pint of beer, or a shot of spirits straight or mixed.

After giving informed consent, participants were screened on the basis of their medical records. The study was approved by the University of Sussex Ethics Committee. Participants with dyslexia, current symptoms of mental illness or neurological diseases, a history of severe mental illness, or any psychotropic medication or drug or alcohol abuse, or altered metabolism of alcohol (e.g. impaired liver function or gastroenteritis) were excluded from the study. Participants were instructed to abstain from the use of illicit recreational drugs for at least 1 week prior to the experiment, from the use of sleeping tablets or hayfever medication for at least 48 h, and from the use of alcohol for at least 12 h prior to the experiment. In addition, participants were instructed to abstain from drinking coffee or tea in the mornings prior to the experiment, but to eat a low-fat breakfast and lunch on the days of testing.

Design

All participants participated in two experimental sessions on consecutive days. Each participant was randomly assigned to one of four treatment conditions (n=12, with equal numbers of males and females per group): alcohol on day 1 (encoding) and day 2 (retrieval); placebo on day 1 (encoding) and day 2 (retrieval); placebo on day 1 (encoding), alcohol on day 2 (retrieval); alcohol on day 1 (encoding), placebo on day 2 (retrieval).

Materials

A set of 80 pairs of concrete nouns consisting of three to seven letters were selected. The first three letters of each of the 160 words (or the first two letters in the case or three letter words) were able to form at least three possible different completions. Half of the word pairs were semantically related, the other half were not. Related and unrelated pairs were originally chosen from Postman and Keppel's "Norms of Word Association" (1970), and previous work in this laboratory (Koeman et al. 1993). Word pairs were then divided into high- and low-association items on the basis of a pilot study in which 12 participants rated relatedness of word pairs on a scale between 1 ("not at all related") to 10 ("very much related"). High-association pairs were those with a "relatedness" score greater than 5, low-association pairs were those with a value smaller than 5. The word pairs were divided into two equal sets (A and B), each containing 20 high- and 20 low-association pairs, for use as alternative study lists (studied or non-studied). The sets were counterbalanced for association ratings, as well as differences in word frequency (Kucera and Francis 1967), imagery and length within a pair. Low and high association words were also equated for the number of stem completions. These materials are the same as those used in the accompanying study (Weissenborn and Duka 2000).

Two alternative test lists were used, each consisting of 80 different three-letter and two-letter word stems. Within each test list, half of the stems were from set A and half from set B, so that each list contained equal numbers of studied and non-studied items for each participant. The non-studied items were included to give a baseline priming measure. Each participant completed both word stem tests and was therefore tested on all studied items. In each test condition, a word stem list was used for cued recall in half of the participants and for word stem completion in the other half, and vice versa, so that both study and test lists were fully rotated across all experimental conditions.

Alcohol administration

Alcohol was administered as a dose of 0.8 g/kg, with 90% v/w alcohol diluted with tonic water (Schweppes Ltd, Uxbridge, UK) to make up a 300 ml beverage. The drink was mixed with Tabasco sauce (McIlhenny Co., Avery Island, Calif., USA) to mask the taste of alcohol and divided into 10×30 ml portions. The placebo beverage consisted of 300 ml tonic water and Tabasco sauce only. Participants were instructed to consume the beverage over a 30-min period, drinking one portion every 3 min.

Memory measurements

Acquisition (immediate recall)

During acquisition, participants studied either list A or list B. Word pairs on the lists were presented one after the other on a computer screen. Presentation of words on the left or right hand side of the word pair was counterbalanced within drug groups. Participants were instructed to read both words in a pair out loud and point to the word they preferred (to distract from the nature of the memory test). Participants were then asked to solve four mental arithmetic problems presented one after the other on the screen (e.g. 4×5; 17–9; 22+24) and then to recall the two items presented prior to the mental arithmetic. The next word pair was then presented on the screen. The experimenter recorded the preferred words, the number of mental arithmetic errors, and the number of words correctly recalled. The dependent variables number of mental arithmetic errors, and the number of words correctly recalled were analysed to evaluate successful acquisition. The acquisition procedure lasted for approximately 25 min.

Retrieval (word stem completion)

At retrieval, participants first carried out an implicit and then a cued recall word stem completion task (Java 1994).

Implicit stem completion (IM task). For word stem completion, participants were presented with the lists of word stems printed on a sheet of paper and instructed quickly to complete each stem with the first English word that came to mind that was not a proper noun. After all stems had been completed, a recognition test was performed, in which participants were asked to go through the list of completed stems and pick out those items that were recognised from the original study set (variable "aware"); words from the original study set not recognised created the variable "unaware". The total number of words completed correctly from the studied list represented the measure of IM. In addition, each recognised item was to be marked with an "R" for "remember" if the item was consciously recollected (variable "recollection") or a "K" for "know" if it was known for a fact that the word had been presented as a study item (variable "familiarity"). Variables were calculated as proportions of the total number of studied words in the list.

Cued recall stem completion (EM task). At cued recall participants were instructed to use the word stems as cues to remind them of study items presented on the previous day. Only those items that could be recalled were to be completed and marked at the same time with an "R" (variable "recollection") or a "K" (variable "familiarity") as appropriate. The total number of words completed correctly from the studied list represented the measure of EM.

It was made clear to the subjects that a remember response reflects the conscious recollection of the context of the study event, whereas a know response refers to the knowledge or the item's presence on the study list in the absence of conscious recollection.

Prior to testing, participants were given typed and oral instructions explaining "remember" and "know" responses. It was made clear that a "remember" response reflects the conscious recollection of the context of the study event, whereas a "know" response refers to the knowledge or the item's presence on the study list in the absence of conscious recollection.

Subjective self-ratings

Profile of Mood States (POMS; McNair et al. 1971)

The POMS consists of 72 mood related adjectives which participants were instructed to rate on a 5-point scale ranging from "not at all" (0) to "extremely" (4). Through the process of factor analysis, eight factors have been established: Anxiety, Fatigue, Depression, Anger, Vigor, Confusion, Friendliness, and Elation. In addition, two other factors can be computed: Arousal=(Anxiety+Vigor)–(Fatigue+Confusion), and Positive Mood=Elation–Depression. Only the two additional factors were evaluated to examine whether alcohol in this dose would have a sedative or a stimulant effect. The POMS were administered to participants before and 30–45 min after drug administration on day 1 and on day 2.

Procedure

Acquisition and retrieval tests were conducted on 2 consecutive days in either morning or afternoon sessions. On arrival in the laboratory on day 1, participants were questioned about alcohol and other drug use in the previous week. All of the participants reported compliance with the inclusion criteria listed above.

A baseline vocabulary measure was obtained using the Mill Hill Vocabulary Scale (Raven 1982). Baseline mood prior to beverage consumption was measured with the POMS questionnaire, and participants' baseline breath alcohol concentrations (BACs) were measures using a standard breathalyser with a detection limit equivalent to 0.01 g/l alcohol in the bloodstream (Alcoholmeter S-D3M; Laborservice GmbH, Germany). Participants then consumed their beverages. A further BAC reading was taken 10 min after consumption (40 min after the start of drinking) of the beverage, and subsequently at 30-min intervals. Data are given from the first two measurements after consumption (40 and 70 min after initiation of drinking). Participants were then taken to the testing room where they completed the acquisition procedure and a further POMS questionnaire. Subsequently, a range of computerized cognitive tests from the Cambridge Neuropsychological Automated Test Battery (CANTAB; Morris et al. 1987) were conducted. Testing lasted for approximately 30 min, and the results are reported elsewhere (Weissenborn and Duka, in preparation). Participants were then given a number of questionnaires to complete during the next 15 min (to be described elsewhere). Once BACs had fallen to below 0.4 g/l, participants gave consent that they would not drive, ride a bike or operate any kind of machinery for 2 h and were released from the laboratory.

On day 2, participants completed a further POMS questionnaire and consumed the beverage as on day 1. BACs were measured before the start of drinking, 10 min after consumption (40 min after the start of drinking) of the beverages and at 30-min intervals afterwards. Data are given from the first two measurements after consumption (40 and 70 min after initiation of drinking). Ten minutes after drinking the beverage, participants were taken to the testing room to perform the retrieval task as described above, first the stem-completion task, and then the cued recall task. Sixty minutes from the end of drinking participants completed Cloninger's Trait and Character Inventory (TCI; Cloninger 1994); the results from this test will be reported elsewhere (Weissenborn and Duka, in preparation). At the end of the session participants were asked to rate the relatedness of words within the 80 word pairs used on a scale between 1 ("not at all related") and 10 ("very much related"). Participants were subsequently debriefed and released from the laboratory as above.

Statistics

For the implicit stem completion task, dependent variables were: i) proportion of items from the study list correctly completed (studied items; IM); ii) proportion of items completed from the studied list and recognised ("aware");iii) proportion of items completed from the studied list but not recognised ("unaware"); iv) proportion of items completed from the studied list recognised and recollected ("remember" or "recollection"); v) proportion of items completed from the studied list recognised but not recollected ("know" or "familiarity"). Proportion of items completed correctly from the non-studied list was used as baseline (non-studied items).

For the cued recall stem completion task, dependent variables were: i) proportion of items from the study list completed correctly (EM); ii) proportion of items completed from the studied list and recollected ("remember" or "recollection"); iii) proportion of items completed from the studied list but not recollected ("know" or "familiarity"). Proportion of items completed which were not from the studied list ("lures") was used as baseline.

For each of the variables from the "studied words", proportion of items completed from the high and low association items were also calculated.

For each stem completion task, probability scores were analysed using repeated measures ANOVA with drug condition at encoding (E; two levels: Alcohol/Placebo) and drug condition at retrieval (R; two levels: alcohol/placebo) as between-subjects variables and item-type (studied versus non-studied) as well as association (high versus low) as within-subjects variables.

ANOVAs were then calculated for the studied words using judgement ("remember" versus "know") or awareness ("aware"/"unaware") instead of item-type as within-subjects variable. Any interactions of between×within factors were further analysed using independent or paired-sample *t*-tests as appropriate. Independent *t*-tests were performed between different treatment combinations at encoding and retrieval. In addition, independent *t*-tests were performed between the group same drug-state (SS) and the group different drug-state (DS) at encoding and retrieval independently of whether the treatment was alcohol or placebo to evaluate drug-state dependent effects more generally.

Comparisons of implicit and cued recall stem completion

To analyse differential effects of alcohol or placebo at encoding and/or at retrieval on IM versus EM we compared completion probabilities and judgements for high or low associations in the two tasks with regard to treatment. Scores of EM and IM were corrected for baseline, and a mixed ANOVA of the factors task (IM/EM), judgement: ("remember"/"know"), association (high/low) as within-subjects and drug at encoding (alcohol/placebo), drug at retrieval (alcohol/placebo) as between-subjects factors, was performed.

For the "arousal" and "positive mood" factors of the POMS questionnaire subjective ratings, a two-way mixed ANOVA with treatment group as between-subject factor (two levels: alcohol or placebo) and session as within-subject factor (two levels: before and after drug administration). Separate ANOVAs were performed for day 1 and day 2.

Results

Age, alcohol use and breath alcohol concentrations

Drug groups did not differ in terms of age [$F(3,44)=2.55$, NS] or self-reported alcohol use [$F(3,44)=2.45$, NS]. Breath alcohol concentrations measured 10 min after the end of alcohol consumption, immediately prior to acquisition on day 1 (BAC1) ranged from 0.42 to 1.11 g/l (mean=0.74 g/l, SEM=0.04). BACs measured 30 min later at the end of acquisition (BAC2) ranged from 0.42 to 1.01 g/l (mean=0.71 g/l, SEM=0.03). On day 2, BACs ranged from 0.29 to 0.98 g/l (mean=0.69 g/l, SEM=0.04) 10 min after the end of drinking and immediately prior to recall, and from 0.34 to 0.97 g/l (mean=0.66 g/l, SEM=0.04) measured 30 min later at the end of recall. Average BACs on days 1 and 2 in the three groups receiving alcohol are shown in Table 1. BACs did not differ between groups on day 1 (BAC1: $t=-1.08$, NS; BAC2: $t=-0.44$, NS) or on day 2 (BAC1: $t=0.57$, NS; BAC2: $t=-1.29$, NS; $df=22$).

Verbal ability and immediate recall

Participants achieved an average score of 15.1 out of 20 (SEM=0.3) on the Mill Hill Vocabulary Scale, and scores did not differ between drug groups [$F(3,44)=0.26$, NS]. Immediate recall scores and the number of errors made in the mental arithmetic tasks during acquisition for the four drug groups are shown in Table 2. Groups did not

Table 1 Breath alcohol concentrations measured prior to (*BAC1*) and after (*BAC2*) acquisition (*day 1*) and recall (*day 2*), *A* alcohol, *P* placebo

Day 1			Day 2		
Treatment group	BAC 1	BAC 2	Treatment group	BAC 1	BAC 2
A at E	0.69 (0.07)	0.70 (0.04)	A at R	0.71 (0.06)	0.60 (0.05)
A at E	0.79 (0.05)	0.73 (0.04)	P at R	–	–
P at E	–	–	A at R	0.67 (0.05)	0.70 (0.05)

Table 2 Number of items recalled correctly [mean (SEM)] and number of maths errors [mean (SEM)] made during the acquisition task on day 1. *A* alcohol, *P* placebo

Measurements	Treatment group			
	A at E		P at E	
	A at R	P at R	A at R	P at R
Immediate recall (no. of words)	72.92 (1.80)	75.17 (1.41)	76.50 (1.32)	75.58 (0.63)
Maths errors (no. of errors)	12.83 (2.23)	8.00 (1.92)	10.58 (2.44)	10.83 (2.38)

Table 3 Effects of alcohol at encoding and/or retrieval on states of awareness in implicit stem completion for high (*H-Ass*) and low (*L-Ass*) association items

Type of response	Implicit word stem completion [completion rates; mean (SEM)] Treatment groups							
	A at E				P at E			
	A at R		P at R		A at R		P at R	
	H-Ass	L-Ass	H-Ass	L-Ass	H-Ass	L-Ass	H-Ass	L-Ass
"Remember"	0.06 (0.02)	0.08 (0.02)	0.12 (0.03)	0.11 (0.03)	0.13 (0.04)	0.08 (0.02)	0.15 (0.03)	0.11 (0.02)
"Know"	0.08 (0.02)	0.07 (0.02)	0.12 (0.02)	0.08 (0.02)	0.11 (0.03)	0.12 (0.03)	0.08 (0.02)	0.10 (0.04)
"Unaware"	0.13 (0.03)	0.13 (0.02)	0.13 (0.03)	0.16 (0.03)	0.09 (0.02)	0.10 (0.02)	0.08 (0.02)	0.11 (0.01)
Studied	0.29 (0.04)	0.27 (0.03)	0.36 (0.04)	0.35 (0.03)	0.33 (0.04)	0.30 (0.02)	0.30 (0.03)	0.32 (0.04)
Non-studied	0.14 (0.03)	0.19 (0.02)	0.26 (0.03)	0.2 (0.02)	0.19 (0.03)	0.17 (0.01)	0.19 (0.02)	0.21 (0.02)

differ significantly in terms of the number of items recalled [$F(3,44)=1.46$, NS], or the number of maths errors [$F(3,44)=0.71$, NS].

Implicit and explicit memory measurements

Mean association ratings obtained at the end of testing confirmed that participants classified all word pairs as of "related" or "unrelated" according to the pilot experiment.

Implicit stem completion

Table 3 presents probabilities of recollective experience ("remember") and familiarity ("know") as well as the probability of state of awareness ("unaware") with regard to studied and correctly completed target items for high and low association items separately. Baseline completion rates are also given (non-studied words).

Stem completion of studied and non-studied items. A mixed 2(drug at encoding: placebo versus alcohol)×2(drug at retrieval: placebo versus alcohol)×2(item type: studied versus non-studied)×2(association: high versus low) ANOVA on the dependent variables completion probabilities showed a significant main effect of item type [$F(3,44)=86.79$, $P<0.01$], confirming the priming effect. There was also a main effect of "drug at retrieval" which approached significance [$F(1,44)=3.94$, $P=0.053$]; participants who had received placebo at retrieval completed generally more word stems. All other main effects or interactions did not reach significance [$F(1,44)<2.87$, NS].

Stem completion of studied items. A further mixed 2 (drug at encoding: placebo versus alcohol)×2(drug at retrieval: placebo versus alcohol)×2(awareness: aware versus unaware)×2(association: high versus low) ANOVA on the dependent variables completion probabilities of correctly completed study items showed a significant main effect of awareness [$F(1,44)=15.48$, $P<0.001$], indicating that participants were more aware than unaware of correctly completed items. No other main effects reached significance [$F(1,44)<1.46$]. There was a significant interaction effect between "drug at encoding" and awareness [$F(1,44)=4.91$, $P<0.05$; Fig. 1]. Post hoc tests showed that participants who had received alcohol at encoding were more unaware of correctly completed items than participants who had received placebo at encoding ($t=2.50$, $df=46$, $P<0.05$). There was no difference between the two groups for the aware items completed ($t=-1.44$, $df=46$, NS). In addition, participants who had received placebo at encoding were more aware than unaware of correctly completed items ($t=5.62$, $df=23$, $P<0.001$), whereas no difference was found between aware and unaware for participants who received alcohol at encoding ($t=1.04$, $df=23$, NS). No other interaction reached significance [$F(1,44)<2.31$, NS]. Lack of any interaction between drug at encoding and drug at retrieval indicated no drug-state context effect.

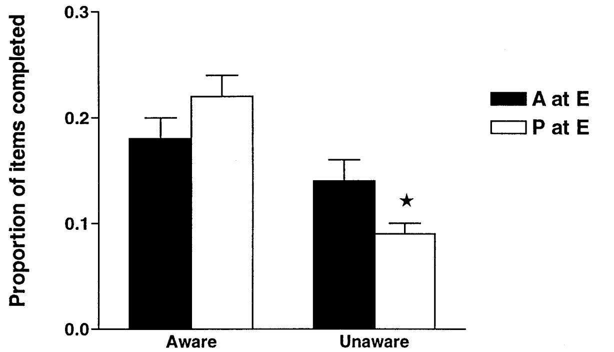

Fig. 1 Probabilities of implicit stem completion (mean±SEM) from the studied words of which participants were aware or unaware. The data are presented separately for the participants who received alcohol and the participants who received placebo at encoding (*A* at *E* and *P* at *E*, respectively). *$P<0.05$ compared to "aware" under *P* at *E* (independent tests) and to "unaware" under *A* at *E* (paired tests)

Analysis of completion probabilities in terms of "remember" and "know" judgements for the aware respons-

Table 4 Effects of alcohol at encoding and/or retrieval on recollective experience and familiarity in explicit cued recall stem completion for high (*H-Ass*) and low (*L-Ass*) association items. *A* alcohol, *P* placebo

Type of response	Cued recall word stem [completion rates; mean (SEM)] Treatment groups							
	A at E				P at E			
	A at R		P at R		A at R		P at R	
	H-Ass	L-Ass	H-Ass	L-Ass	H-Ass	L-Ass	H-Ass	L-Ass
"Remember"	0.23 (0.03)	0.15 (0.03)	0.23 (0.05)	0.10 (0.03)	0.18 (0.04)	0.11 (0.03)	0.30 (0.04)	0.16 (0.03)
"Know"	0.10 (0.02)	0.11 (0.02)	0.23 (0.03)	0.18 (0.04)	0.20 (0.04)	0.15 (0.03)	0.08 (0.02)	0.14 (0.03)
Studied	0.32 (0.04)	0.27 (0.03)	0.45 (0.05)	0.28 (0.05)	0.38 (0.04)	0.26 (0.03)	0.37 (0.05)	0.30 (0.05)
Non-studied	0.08	0.08	0.04	0.08	0.04	0.03	0.05	0.08

es was performed using a mixed 2(drug at encoding: placebo versus alcohol)×2(drug at retrieval: placebo versus alcohol)×2(judgement: remember versus know)×2(association: high versus low) ANOVA revealed no significant main effects or interactions [$F(1,44)<2.69$, NS; see Table 3].

Cued recall stem completion

Table 4 presents probabilities of recollective experience ("remember") and familiarity ("know") with regard to studied and correctly completed target items for high and low association items separately. Baseline completion rates are also given [non-studied items (lures)].

Stem completion of studied and non-studied items. A mixed 2(drug at encoding: placebo versus alcohol)× 2(drug at retrieval: placebo versus alcohol)×2(item-type: studied versus non-studied)×2(association: high versus low) ANOVA on the completion probabilities showed a significant main effect of item-type, more "studied" than "non-studied" items were completed [$F(1,44)=197.98$, $P<0.001$]. In addition, more high than low association items were correctly completed [$F(1,44)=13.38$, $P<0.001$]. Post-hoc analysis of a item-type×association interaction [$F(1,44)=22.3$, $P<0.01$] confirmed the effect of association for studied items ($t=4.56$, $P<0.001$, $df=47$), but not for non-studied items ($t=-1.54$, NS, $df=47$). No main effect of drug group was observed [$F(1,44)<1.21$, NS], and interactions involving group remained non-significant [$F(1,44)<3.03$, NS].

Stem completion of studied items. A further mixed 2(drug at encoding: placebo versus alcohol)×2(drug at retrieval: placebo versus alcohol)×2(judgement: remember versus know)×2(association: high versus low) ANOVA on the completion probabilities of study items, showed a significant main effect of association [$F(1,44)=21.2$, $P<0.001$] but no main effects of either group [$F(1,44)<1.47$, NS] or judgement [$F(1,44)=2.54$, NS]. Post-hoc analysis of a significant judgement×association interaction [$F(1,44)=12.86$, $P<0.01$] showed that

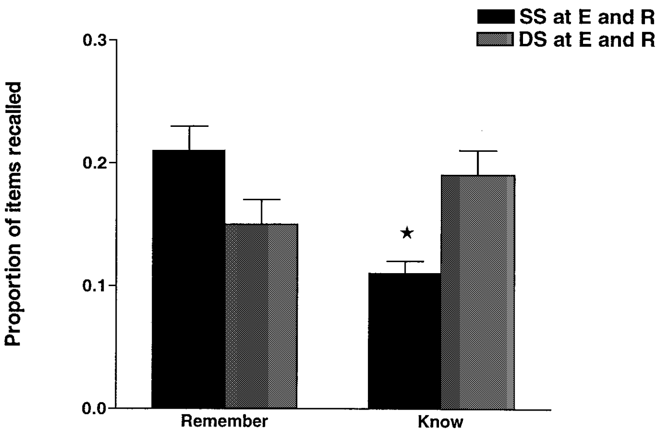

Fig. 2 Probabilities of "remember" and "know" responses of cued recall stem completion for the group of participants tested under same drug-state (*SS*) or under different drug-state (*DS*) conditions at encoding (*E*) and retrieval (*R*). *$P<0.001$ compared to "know" responses under DS (independent tests) and to "remember" responses under SS (paired tests)

participants made more "remember" than "know" responses for high but not low association items (high: $t=-2.79$, $df=47$, $P<0.01$; low: $t=0.78$, $df=47$, NS). In addition, participants "remembered" more high than low association items ($t=5.32$, $df=47$, $P<0.001$) but "knew" the same number of high and low association items ($t=0.06$, $df=47$, NS; see Table 4).

A significant encoding×retrieval×judgement interaction [$F(1,44)=10.98$, $P<0.01$] was further examined using a two-way ANOVA separately for "know" and "remember" responses. A significant interaction between encoding and retrieval was found for the "know" responses, whereas the interaction for the "remember" responses only approached significance [$F(1,44)=11.12$, $P<0.01$ and $F(1,44)=3.18$, $P=0.08$, respectively]. That is, different-state groups (DS) made more "know" responses than same-state groups (SS; $t=-3.38$, $df=46$, $P<0.01$). In addition, participants in the same-state group gave more "remember" than "know" judgements ($t=-4.54$, $df=23$, $P<0.001$), whereas participants in different-state groups did not ($t=1.05$, $df=23$, NS; Fig. 2).

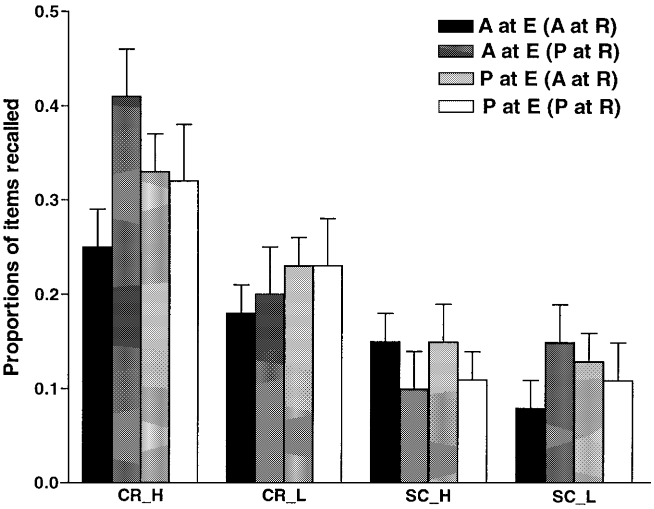

Fig. 3 Proportions of word stems completed in the explicit and implicit tasks corrected for baseline for high and low associations and for the different treatment conditions. *CR_H* cued recall for high associations, *CR_L* cued recall stem completion for low associations, *SC_H* implicit stem completion for high associations, *SC_L* implicit stem completion for low associations, *A* alcohol, *P* placebo, *E* encoding, *R* retrieval

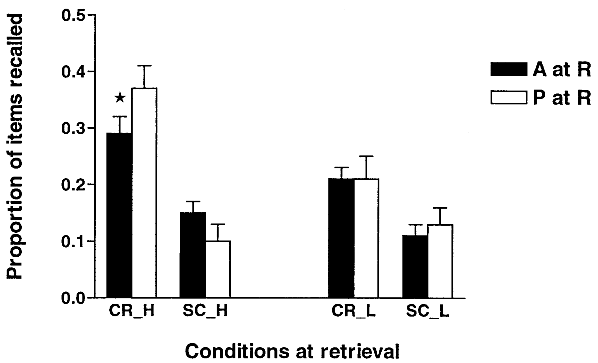

Fig. 4 Proportions of word stems completed in the explicit and implicit tasks corrected for baseline for high and low associations. The data are presented separately for the participants who received alcohol and the participants who received placebo at retrieval (*A* at *R* and *P* at *R*, respectively). *CR_H* cued recall stem completion for high associations, *CR_L* cued recall stem completion for low associations, *SC_H* implicit stem completion for high associations, *SC_L* implicit stem completion for low associations. *P<0.001 compared to CR_H under P at R (independent tests)

Comparisons of implicit and cued recall stem completion

To compare completion probabilities in the two tasks (IM and EM) with regard to treatment, scores were corrected by subtracting the baseline (non-studied words; Fig. 3). A mixed 2(drug at encoding: placebo versus alcohol)×2(drug at retrieval: placebo versus alcohol)×2(association: high versus low)×2(task: implicit versus explicit) ANOVA on the completion probabilities showed higher correct completion rates for cued recall than for word stem completion [$F(1,44)=54.97$, $P<0.001$]. The effects of association and task×association interaction were also found to be significant [association: $F(1,44)=11.96$, $P<0.001$; task×association: $F(1,44)=11.62$, $P<0.001$]. Post-hoc analysis of this interaction confirmed that participants recalled more high than low association items during cued recall ($t=4.65$, $df=46$, $P<0.001$), while the difference was non-significant in the word stem completion task ($t=0.31$, NS). While the main group effects (drug at encoding or at retrieval) did not reach statistical significance [$F(1,44)<0.38$, NS], there was a significant drug at retrieval×association×task interaction [$F(1,44)=4.56$, $P<0.05$)]. A further mixed 2(drug at retrieval: placebo versus alcohol)×2(task: implicit versus explicit) ANOVA separately for high and low associations showed a significant task×drug at retrieval interaction in the case of high [$F(1,44)=4.80$, $P<0.05$] but not low associations [$F(1,44)=0.15$, NS; see Fig. 4]. Cued recall of high association items was lower in the group which had alcohol than the group which had placebo at retrieval ($t=7.67$, $df=23$, $P<0.001$), while almost the opposite was true for the stem completion (no significant differences were found in post-hoc independent *t*-tests).

Subjective self-ratings

POMS

Table 5 shows means and SEM of "arousal" and "positive mood" scores tested before and after alcohol or placebo for day 1 and day 2. A significant decrease of "arousal" was found from pre to post treatment session [$F(1,45)=16.47$, $P<0.001$] only on day 1. In addition, a significant interaction between treatment and session was found for the "positive mood" factor on day 1 [$F(1,45)=5.88$, $P<0.05$]. Post-hoc tests to explore this in-

Table 5 "Arousal" and "Positive Mood" mean scores (SEM) of the POMS questionnaire for alcohol or placebo treatments and on day 1 and day 2

POMS score	Day 1 (encoding)				Day 2 (retrieval)			
	Alcohol		Placebo		Alcohol		Placebo	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Arousal	0.31 (0.31)	–0.07 (0.30)	0.90 (0.25)	–0.14 (0.27)	0.84 (0.25)	0.24 (0.24)	0.50 (0.34)	0.28 (0.23)
Positive mood	1.03 (0.21)	1.32 (0.21)	1.21 (0.14)	0.89 (0.17)	1.38 (0.16)	1.25 (0.18)	1.22 (0.19)	1.07 (0.17)

teraction showed a significant decrease of "positive mood" from pre- to post-treatment measurements in the placebo group (t=2.43, df=22, P<0.05), but there was no difference between pre- and post-treatment measurements in the alcohol group. There were no other effects found on either day.

Discussion

The important findings of the present study can be summarised as follows: The study has demonstrated that alcohol had no effect on overall performance in recognition tasks but influenced states of awareness of memories. Alcohol was also found to diminish the beneficial effect of semantic context (high associations) at retrieving memories via effortful (EM) rather than automatic influences (IM). These effects of alcohol were dependent largely on alcohol given at encoding although alcohol given at retrieval may have potentiated these effects. The doses of alcohol were equivalent to 4–5 units, which gave BAL of approximately 0.7 g‰. A dissociation between explicit and implicit memory with respect to independent context (drug-state) has also been shown. Drug state-dependent retrieval effects were found on EM but not IM measurements. In addition, greater recollection than familiarity for explicitly retrieved items was reported under same drug state whereas different drug state between encoding and retrieval facilitated familiarity responses.

Implicit word stem completion (implicit memory)

The stem completion task performed by the participants under the instruction "complete the stems with the first word that comes to mind" gave a good measure of a priming effect since participants used words from the study lists to complete the stems rather than alternatives words of the same frequency (an "indirect" test of memory). The "remember" or "know" response following implicit stem completion as suggested by Gardiner and Java (1990) allowed a separation of memories with awareness (items given either a "know" or a "remember" response) from memories without awareness. Although participants were generally more aware than unaware of their implicit memories (a main effect of awareness was found to be significant) their "remember" or "know" responses for the completed words that they recognised as being from the list, did not differ indicating that a primed item with subject's awareness can equally be recollected or found familiar (Reingold and Goshen-Gottstein 1996).

Equally, there was no superiority for the high association words stem completion over the low association words either in the "know" or "remember" response, thus semantic (interactive) context had no effect on priming. This finding contradicts previous reports showing an effect of related versus unrelated words or meaningful versus non-meaningful words on priming (Gardiner and Java 1990). Further research needs to determine the discrepancy whether is just of question in lack of power or differences in experimental procedure.

Since the superiority of high versus low associations was not found for the "remember" responses one could argue that the attribution of "remember" or "know" responses after implicit stem completion may not necessarily reflect the type of processes that participants have employed during completion, i.e. performance in this task may have not been contaminated by conscious processes. Nevertheless the additional estimation of "remember" or "know" responses allows us to estimate the probabilities of stem completion in an unaware state of using memories, which reflects, as argued by Java (1994), perceptual processing a form of automatic influences of memory. When alcohol was given at encoding, although it did not alter performance in the task generally, it decreased the awareness for stem completion of study items, thus increasing the relative amount of automatic influences of memory. These data with alcohol parallel the data demonstrated by Jacoby (1996) on priming using divided attention in the study phase. Jacoby (1996) found that divided attention increased probabilities of completing word fragments with a studied word under the "exclusion" condition where participants were asked to complete the fragments trying to exclude the studied words. If a participant completed a fragment with a word from the study list, he or she must have been in an unaware state comparable to that in our experiment.

The effects of alcohol to decrease attentional recourses or to inhibit allocation of attention to test requirements has been previously described (Moskowitz and de Pry 1968; Stephens et al. 1992). It is reasonable then to suggest that alcohol by influencing attention has reduced the efficiency of encoding, and subsequently reduced the probability of recollection and increased the relative automatic influences of memory. In a recent study, we have demonstrated the detrimental effects of alcohol on recollection in a task of free recall (Weissenborn and Duka 2000). Lack of an alcohol effect on overall performance in the implicit stem completion task parallels the data reported by Hashtroudi et al. (1984), who showed that intoxicated subjects were able to identify degraded words to the same degree as sober subjects if they had been preexposed to the words. Hashtroudi and his colleagues, however, did not identify states of awareness of memories experienced by the subjects.

There were no effects of drug state on the automatic influences of memory. It has been suggested that indirect tests depend more on surface processing than on conceptual processing. For example manipulations of modality are shown to be important for indirect but not for direct tests (Jacoby and Dallas 1981; for a review Schacter 1980). The concept of encoding specificity (Tulving and Thomson 1973) suggests that a set of cues reinstated at retrieval could automatically influence memories. Thus retrieval cues should also facilitate automatic influences of memory as tested in the present study. However, neither semantic context (high versus low associations; interactive context, Baddeley 1982) nor drug-state (independent context) had an effect on the implicit task. We had predicted that interactive context would be more likely to influence recollective experiences whereas independent context would affect automatic operations at retrieval. That interactive context was not effective can be understood. Participants were required to complete the stems with the first word in mind, thus their search strategy was not actively directed to the contextual cues that the studied words were providing. Several studies have also shown that automatic processes were unaffected by level of processing manipulations (Toth et al. 1994) and that repetition priming for words presented as pairs at encoding is not present under automatic influences of memory (Graf and Schacter 1985, 1987, 1989; but they argued that there was implicit memory for new associations). Environmental context, however does not provide any contextual cue which would interact with the meaning of the word and therefore may be more important for automatic influences of memory. However, our data suggest that this may not be the case. Taking all these data together, it could be suggested that all the measures of the implicit tasks used in the present study reflected automatic influences of memory. Further more attribution of awareness by the participants on the automatic influences of memory revealed a selective effect of alcohol to reduce awareness without reducing the automatic influences of memory. This effect of alcohol was more pronounced when alcohol was given at encoding.

Cued recall word stem completion (explicit memory)

The effects of alcohol on recollective experiences were tested by a cued recall task where the cue was provided by the word stem. Participants were required to try to complete the stems using words from the study list (a “direct” test of memory). The concept of recollection however does not deny that automatic processes form an important part of retrieval. Therefore the “remember” and “know” responses were used to separate memories with from memories without recollection. Alcohol did not affect overall performance except as an independent context (drug-state; see also discussion bellow). Lack of a deleterious effect of alcohol given at encoding only on “remember” responses is in contradiction to the data reported by Curran and Hildebrandt (1999) who found that alcohol given at encoding impairs retrieval at a later stage for the “remember” responses. One way to explain this different result may be a state dependency effect. Subjects in the Curran and Hildebrandt (1999) study who had alcohol at encoding performed under a different drug state (alcohol is assumed not to be present), whereas subjects who had placebo at encoding performed under same drug state at retrieval. Our data on the “remember” responses have also shown that at different drug state between encoding and retrieval there is a tendency (the interaction between encoding and retrieval for the “remember” responses only approached significance) for the “remember” responses to decrease. Further research on state dependency retrieval needs to clarify the discrepancy.

The context provided by the high associations (interactive context) had an effect on recollective experiences but no effect on familiarity. This finding gives further evidence that memories without recollection remain unaffected by the context related to the meaning of the stimulus (interactive; see also discussion above) whereas recollective experiences benefit from such contextual cues paralleling several reports in the literature (for review see, Schacter 1987; Kirsner 1998).

When the drug state as a context was evaluated it was revealed that under similar drug states participants had more recollective than familiarity experiences, whereas under different drug states participants experienced recollection and familiarity to the same extent. Thus the drug-induced internal state of the subject reinstated at retrieval enhanced accessibility of the memory trace. These data parallel reports in the literature with drug as an independent context. These data furthermore give evidence that independent context can facilitate also cued recall and not only free recall (Eich 1980; Baddeley 1982). However, its effect becomes apparent only in cued recall accompanied by recollective experience. Such a finding supports the issue raised by Jacoby and Dallas (1981) of two bases of recognition the “perceptual recognition” and “recognition memory” which can be labelled alternatively familiarity and recollective experience. We have also recently demonstrated (Weissenborn and Duka 2000) that alcohol as an independent context might facilitate retrieval tested in a free recall paradigm. However, this state dependent effect was seen as a competition between high and low associations, i.e. in the presence of the same state less low and more high associations were recalled whereas total recall did not benefit. We have suggested that this differential effect of alcohol as a state on high and low associations might have been the result of a limited capacity of the system using all the available retrieval cues. Since familiarity did not benefit from the interactive context (high associations) in the present study it was not possible to show a differential effect of drug state on high versus low associations. Although the effect of drug state to facilitate recollective experience on the basis of the evidence in the literature (Weingartner and Murphy 1977; Kent et al. 1986; Lowe 1986) is easy to understand the increased familiarity responses in different drug compared to same drug state is puzzling. A reasonable question to pose is whether the recollective experience and familiarity are interdependent and serve a limited memory system that trades off between the two. Evidence in the literature suggests that familiarity and recollection function independently (Jacoby 1991). We have also performed post-hoc correlations between “remember” and “know” responses and there was no evidence for any relationship between the two. Do these data suggest that familiarity may be inhibited in the presence of context and that unavailability of retrieval cues would increase familiarity? There is not information in the literature and our data cannot answer this question.

Alcohol in the dose used here (0.8 g/kg) did not affect the arousal state of the participants (as measured by the POMS questionnaire). A decrease in positive mood ratings was found under placebo only on day 1; however, alcohol did not influence the positive mood of the participants. Thus, the effects of alcohol seen in the present study were not confounded by either sedative effects or mood effects of the drug.

When stem completion in the two tasks was analysed to compare explicit ("direct" test of memory) and implicit ("indirect" test of memory) memory directly, several interesting findings were revealed. A superiority of memories was found in the explicit task or direct test of memory when compared with the implicit or indirect memory task. This result supports previous demonstrations that recollection is more efficient in retrieving memories than automatic processing (Jacoby 1996), especially when a deep strategy for encoding is encouraged as in the present study (subjects gave pleasantness ratings during encoding).

The associative repetition effect (greater priming effect for high versus low associations) was only present in the explicit ("direct") memory task suggesting a dissociation between "direct" and "indirect" tests of memory on conceptual processing. A further dissociation between implicit and explicit memory was demonstrated on the basis of alcohol effects. Alcohol given at retrieval decreased explicit memory, particularly the associative repetition effect, whereas implicit memory remained unaffected. It is surprising that there was no effect on explicit memory of alcohol given at encoding as previously shown (Birnbaum et al. 1978, 1980; Hashtroudi et al. 1983; Weissenborn and Duka 2000). This may simply be a power consideration for the current study. Inspection of Fig. 3 revealed that the ability of alcohol at retrieval to decrease cued recall was more pronounced in the group which had alcohol also at encoding. Indeed post-hoc *t*-paired tests demonstrated that while group PA showed greater cued recall than stem completion (t=2.94, df=11, P<0.05), the group AA did not (t=1.73, df=11, NS); we realise that these results need replicating to confirm. Nevertheless, there is compelling evidence that failure to engage in elaborative processing is a critical source of alcohol-related memory impairment (Birnbaum et al. 1980). Additionally, there are studies suggesting that alcohol besides its effect on encoding may have also a detrimental effect on retrieval (Huntley 1974; Maylor et al. 1988; Weissenborn and Duka 2000; for review, see Stephens et al. 1992).

Thus a dissociation of alcohol effects on EM and IM were demonstrated in the present study. Alcohol prior to encoding reduced awareness of implicitly retrieved material, but had no effect on IM per se, confirming previous findings with alcohol (Hashtroudi 1984). Alcohol prior to retrieval (especially if alcohol was given also at encoding) was found to diminish the beneficial effect of interactive context (high associations) in retrieving memories via effortful (EM) rather than automatic influences (IM). In addition, the data provided new evidence for state-dependent retrieval effects on EM but not IM and indicated that different states between encoding and retrieval may increase familiarity of explicitly recalled items.

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