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The Effects of Alcohol on Crime-related Memories: A Field Study

KIM VAN OORSOUW* and HARALD MERCKELBACH

Forensic Psychology Section, Maastricht University, Maastricht, The Netherlands

Summary: This field study investigated to what extent memory of criminally relevant details is affected at (close to) zero ($M_{BAC} = 0.00\%$), moderate ($M_{BAC} = 0.06\%$), and high ($M_{BAC} = 0.16\%$) levels of alcohol intoxication. Participants ($N = 76$) were approached in bars and were invited to watch a mock crime from a perpetrator perspective. We also measured their blood alcohol concentration levels. After 3–5 days, when participants were sober, they underwent a free and cued recall task about the mock crime. Compared with sober controls, both moderately and highly intoxicated individuals were less complete when recollecting crime details, recalling up to 33% fewer correct details. Overall, intoxicated participants were less accurate during the cued recall task (i.e. they produced more errors) relative to sober participants. These accuracy effects were dose-dependent for cued recall of salient features. Implications for police interrogations of defendants are discussed. Copyright © 2011 John Wiley & Sons, Ltd.

Alcohol is reported to be implicated in about 50% of all violent crimes (e.g. Haggard-Grann, Hallqvist, Langstrom, & Moller, 2006). In the Netherlands, 75% of the offenders who had been arrested because they were violent at nightlife parties were intoxicated at the time of their crimes. Eighty-six per cent of them had ingested excessive amounts of alcohol (CVV, 2009). Sigurdsson and Gudjonsson (1994) found that 64% of the prisoners they interviewed were said to have been intoxicated at the time of the crime. Other researchers noticed that about one-third of convicted offenders were reported to have consumed alcohol at the time of the crime (see Evans, Schreiber Compo, & Russano, 2009).

Numerous studies have shown that alcohol not only lowers thresholds for impulsive behaviour, but also has an undermining effect on memory (White, 2003; Fillmore & Vogel-Sprott, 1999). This pattern may confront law enforcement professionals with interpretative problems. Research shows that alcohol undermines memory because it interferes with the encoding and particularly the consolidation of new information (Ray & Bates, 2006; Söderlund, Parker, Schwartz, & Tulving, 2005; Verster, Van Duin, Volkerts, Schrueder, & Verbaten, 2003). More specifically, alcohol disturbs transfer of information from short-term into long-term memory (e.g. White, 2003). Saults, Cowan, Sher, and Moreno (2007) argued that superficial encoding and lack of rehearsal in working memory make new information especially vulnerable to alcohol intoxication. Laboratory studies suggest that, at blood alcohol concentrations (BACs) below 0.15%, memory impairments tend to be small to moderate (grey-outs or fragmentary blackouts) and manifest themselves as difficulties in recalling parts of conversations or words on word lists that have been studied (Goodwin, Othmer, Halikas, & Freeman 1970; Mintzer & Griffiths, 2002; Ray & Bates, 2006; Ryback, 1971).

About 35% of the offenders who have been convicted for violent crimes claim to have an alcohol blackout for their offence (Cima, Nijman, Merckelbach, Kremer, & Hollnack, 2004; Kopelman, 1995). Although alcohol blackouts are frequently reported, they are often fragmentary and not of the full-blown (i.e. *en bloc*) type that offenders of violent crimes claim to have (Van Oorsouw, Merckelbach, Ravelli, Nijman, & Mekking-Pompen, 2004). In fragmentary blackouts, memory formation is partially blocked. Persons experiencing such blackouts claim that they are missing parts of events when they are reminded of these events. These circumscribed memory deficits result from an acute, relatively modest rise in BACs, leading to a disruption of short-term memory (Ryback, 1971).

In general, the magnitude of memory impairments increases with the amount of alcohol that is ingested. Consequently, prolonged rises in BACs may lead to *en bloc* blackouts, which refer to an inability to recall any details of the events (e.g. conversations or behaviour) that happened while intoxicated. Memories of the event cannot be recalled at a later time, neither spontaneously nor with the help of cues. Interestingly, intoxicated persons who subsequently experience a blackout may be conscious and able to engage in a conversation at the time of the intoxication as long as their immediate and remote memory remains intact.

The large majority of lab studies in this domain investigated the effects of moderate dosages of alcohol on memory for isolated words and pictures rather than complex, meaningful material. To the best of our knowledge, only Read, Yuille, and Tollestrup (1992) investigated how moderate dosages of alcohol affect memory for a mock crime. These authors found that, compared with sober controls, intoxicated individuals with BACs of approximately 0.11% recalled fewer correct details of a mock crime. Yet, at BACs of 0.08%, intoxicated participants did not differ from sober controls in the number of correctly recalled information units. Whereas the Read et al. (1992) study is informative, its relevance to forensic experts who are interested in the relationship between high alcohol doses and memory impairments is limited. Generalizability to real-world contexts requires BACs of approximately 0.15% and beyond. (Kalant, 1996; White, 2003). Germane to this is the work by Goodwin and colleagues (Goodwin, Crane, & Guze, 1969; Goodwin, Othmer, Halikas, & Freeman, 1970), who presented their participants with different stimuli while

*Correspondence to: Kim van Oorsouw, Department of Clinical Psychological Science, Forensic Psychology Section, Maastricht University, P.O. Box 616, 6200 MD, Maastricht, The Netherlands.
E-mail: K.vanoorsouw@maastrichtuniversity.nl

they had been drinking considerable amounts of alcohol (i.e. 16–18 oz of bourbon within 4 hours, resulting in BACs up to 0.28%). Follow-up tests at 30 minutes indicated that participants were unable to recall any of the stimuli, suggesting that alcohol had seriously impacted the consolidation of the stimulus material. A limitation of this work, however, is that Goodwin and co-workers mostly relied on clinical samples of people (i.e. alcoholics). Thus, it is not clear to what extent the memory impairments documented in their studies can be fully attributed to acute rises in alcohol levels.

In a field study, Dysart, Lindsay, MacDonald, and Wicke (2002) had their intoxicated participants watch a robbery. Subsequently, they had to identify the perpetrator in either a target-present or target-absent line-up. Like the low-intoxication group (average BAC = 0.02%; range 0.00–0.04%), highly intoxicated individuals (average BAC = 0.09%; range 0.04–0.20%) experienced few difficulties in pointing out the suspect in a target-present line-up. The highly intoxicated participants did, however, make more false identifications in a target-absent line-up (see also Yuille & Tollestrup, 1990). The authors suggest that these false identifications reflect *alcohol myopia*. Alcohol myopia refers to the impairment in perception and the subsequent encoding resulting from alcohol intoxication (Steele & Josephs, 1990). Even at low dosages, attention and visual and auditory information processing are affected by alcohol (Calhoun et al., 2004; Do Canto Pereira, David, Machado Pinheiro, & Ranvaud, 2007; Schweizer et al., 2006). Consequently, a person who has raised alcohol levels can only attend to a limited amount of information, only encodes salient features of an event (e.g. hair style or clothing) and fails to attend to more peripheral details (e.g. moustache or birthmarks). In the study of Dysart et al. (2002), a tendency to select targets on the basis of salient features may account for intoxicated participants' correct identifications in target-present line-ups. However, this tendency may also be responsible for matching salient features of the suspect with those of similar fillers in the target-absent line-up, thereby producing false identifications.

Surprisingly, there have been relatively few studies that looked at the effects of high alcohol levels on memory functioning outside the laboratory. Indeed, as Evans et al. (2009; p. 212) remarked: 'Given the frequency with which intoxicated individuals interact with the criminal justice system, *more research on their possible vulnerabilities is needed*. Only after more empirical research has been conducted, with ecologically valid designs, can comprehensive evidence-based policies for handling intoxicated witnesses and suspects be developed'. With this in mind, we investigated to what extent memory for a mock crime is impaired at acute levels of (close to) zero, moderate, and high alcohol intoxication. Based on previous studies, we hypothesized that, relative to zero and moderate levels of intoxication, higher levels (i.e. BACs above 0.11%) at the time of encoding would result in poorer correct recall of crime details and more errors when sober again. In addition, we were interested in whether we could find support for alcohol myopia. If alcohol, indeed, impairs attention for peripheral details rather than central details, higher levels of intoxication would impair memory for peripheral details to a greater extent than memory for central details.

MATERIALS AND METHOD

Participants

In total, 110 volunteers[1] were recruited in local bars in Maastricht, the Netherlands. Seventy-five participants (36 men) were willing to participate in a follow-up memory test. Their mean age was 21.0 years (range: 18–28 years; $SD = 2.25$). After participation in the follow-up test session, they were provided with the results of the BAC measurement. The study was approved by the local standing Ethical Committee.

Mock crime

The mock crime consisted of a 2.5-minute video footage of a burglary filmed from the perspective of the perpetrator. It was edited in such way that a viewer could easily identify with the perpetrator.[2] The video footage showed how a person entered a house using a lock pick. He/she went upstairs into a room, where he/she stole a laptop computer, money that he/she took from a purse, and a soda taken from the fridge. On his/her way out, the perpetrator also took a bicycle from the hallway. The video footage contained central details (e.g. actions like opening the lock with a lock pick and stealing certain objects) and peripheral details (e.g. pictures on the wall, a red vacuum cleaner, and various types of furniture).

Design and procedure

The independent variable in the current study was the level of intoxication (see the succeeding paragraph).The dependent variables were scores on free and cued recall. We performed repeated measurement analyses of variance (ANOVAs) on the free recall data with group (sober, moderately intoxicated, severely intoxicated) as a between-subjects factor and type of detail (central versus peripheral) as a repeated measure.

Participants were approached in bars between 2200 h and 0300 h and invited to participate in a study on alcohol and cognition. After signing an informed consent form, they were taken into a separate room where their breath alcohol concentration (BrAC) was measured using the Lion Alcometer SD400. The breathalyser converts the breath alcohol ratio into blood alcohol ratio in the generated result. Therefore, the estimates collected and reported are of BAC and not BrAC at the time of testing. In addition, participants filled out a questionnaire that asked about their drinking habits, their drug use, their experience with blackouts, and their e-mail address where they could be contacted for a follow-up session. Next, while in a separate and quiet room, participants watched the video footage that was presented on a 14.1-in. screen. They were asked to identify with the perpetrator. After they had seen the video, they were told

[1] Participants were recruited in various bars on different nights of the week, resulting in a mixed sample of students and non-students.
[2] A copy of the video footage is available at YouTube (http://www.youtube.com/watch?v=yMxI5ESkI7A).

that some questionnaires would be sent to them by e-mail within the next couple of days. In return for their participation in this first session, participants received a chocolate bar. Within 3–5 days, participants were separately sent two memory tests in a fixed order; first, they were provided by e-mail with a free recall test, and when they had completed and returned the free recall, a cued recall test followed. Tests were sent in the morning, and participants were instructed to take them only when they were sober and to fill out the questionnaires alone. After they had completed both questionnaires and returned them, participants were fully debriefed, were provided with their BAC level, and were thanked for their participation.

Memory testing

The free recall test asked participants to write down everything they remembered of the video. More specifically, they were asked to give a detailed description of the location, surroundings, and stolen objects.

After they had returned the free recall test, participants were sent within 1 day a cued recall test that asked them to answer specific questions about the mock crime. This test contained 30 questions.[3] Six were about the bar and the BAC level measurement (e.g. 'What bar were you tested at?'; 'Were you tested by a man or a woman?') and 24 were about the video (e.g. 'How did the perpetrator enter the house?'; 'Which objects were stolen?'). Participants also gave confidence ratings for each answer using five-point scales (anchors: 1 = *not confident* to 5 = *very confident*).

Scoring of memory data

A scoring protocol was developed to evaluate participants' free and cued recall. For free recall, 36 critical information units were identified. Of those 36 elements, 19 referred to central details, whereas 17 referred to peripheral details. Examples of central and peripheral details are 'I entered a house' (central detail), 'using a picklock' (central detail), 'there was a poster in the bedroom' (peripheral detail), and 'there was a (white) sofa in the living room' (peripheral detail). For each correctly reported detail, participants received one point. To obtain a total free recall score, the number of correctly recalled information units was summed (maximum = 36). The same was done to obtain separate scores for free recalls of central (maximum = 19) and of peripheral (maximum = 17) details. The 30 questions of the cued recall test listed 43 items,[4] 18 of them referring to central details and 25 of them pertaining to peripheral details. Cues consisted of short questions like 'What objects were stolen?'[5] The maximum score that could be obtained for the cued recall was higher than that for free recall because the questions were more specific and resulted in more detailed recall.

An index of *memory completeness* was obtained by calculating proportions of correctly recalled information for the total free recall, free recall of central details, and free recall of peripheral details. Thus, participants' number of correctly recalled items was divided by the maximum scores for total (i.e. 36), central (i.e. 19) and peripheral (i.e. 17) details, separately. The same scoring procedure was followed to obtain an index of memory completeness for the cued recall, with maximum scores being 43 for the total score, 18 for central, and 25 for peripheral details. In addition, the introduction of new information was scored as a commission error (e.g. 'I stole a cell phone'), and distorted information was scored as a distortion error (e.g. 'the purse was red' when it was green).

To obtain an index of participants' accuracy, *memory accuracy scores* were calculated. Memory accuracy was calculated as follows: correct recall/(number of correctly recalled details + number of commissions + number of distortions). This was done for both free and cued recall parameters, separately.

Free and cued recalls were scored by the first author and an independent rater, who were blind to the participants' intoxication status. Pearson product–moment correlations between the two raters were 0.95 and 0.98 for the free and cued recalls, respectively. For number of commission and distortion errors, they were 0.66 and 0.67, respectively (all $ps < 0.01$). These relatively low interrater reliabilities were caused by disagreement about whether incorrect information was coded as commission or distortion error. In other instances, there was disagreement about how to handle partly correct information.[6] Disagreements were resolved through discussions, resulting in a final dataset.

RESULTS

Statistical analyses

To examine the link between intoxication levels and memory performance, correlations were calculated between BAC and memory scores. To analyse how legally defined intoxication levels affected recall of central and peripheral details, both free and cued recall data were subjected to 3 (groups: sober, moderately intoxicated, severely intoxicated) × 2 (type of detail; central versus peripheral) repeated measures ANOVAs with the last factor being a repeated measure. Follow-up pairwise comparisons were carried out, and because these were exploratory in nature, we report two-tailed results.

Blood alcohol concentrations

As can be seen in Figure 1, the distribution of BAC was positively skewed with the zero blood alcohol level category

[3] An English version of the cued recall test may be obtained from the first author.

[4] There were 43 items because some questions asked for more than one scorable item (e.g. "Which items were stolen?" An answer that would include a laptop computer, money from a wallet, a bike, and a can of coca cola would be rated with four points).

[5] Free recall instructions and cued recall test may be obtained from the first author.

[6] For example, one participant said about the fragment in which the perpetrator stole money from a wallet in a purse: "the wallet was stolen". One rater scored this as a distortion error (e.g. wallet instead of money), whereas the other scored this as correct because the wallet *was* taken from the purse (but put back in there again). Thus, the second rater argued that this free recall reflected better memory performance compared with a person who would not recall taking the money at all.

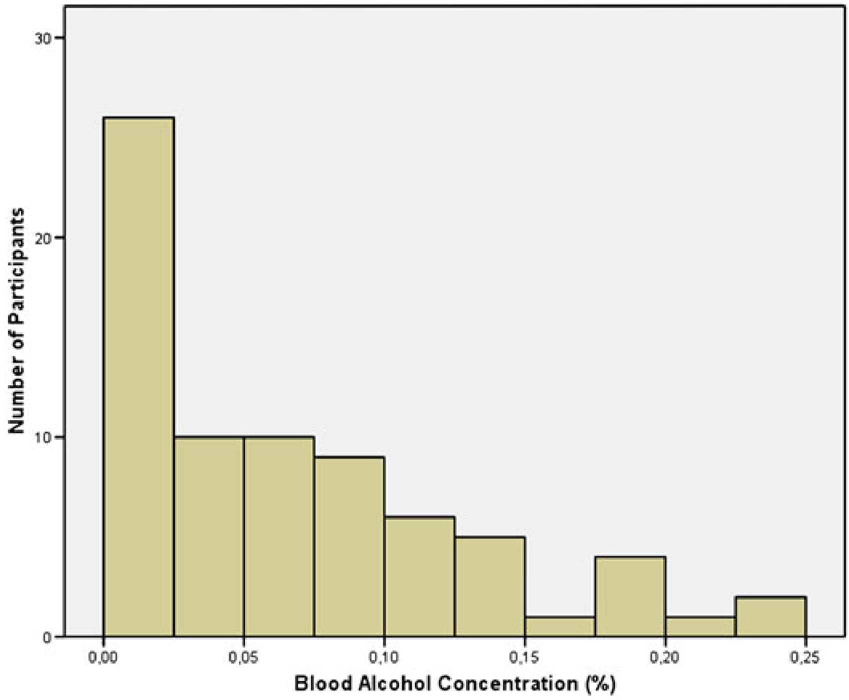

Figure 1. Distribution of blood alcohol concentrations (BACs) in the sample ($N = 74$)

being overrepresented. This is as expected because control participants all fell within this category. BACs ranged between 0.00% and 0.24% with an average BAC of .07% ($SD = 0.06$).[7]

Levels of intoxication and drinking behaviour

In the Netherlands, the maximum concentration of blood alcohol that is legally permitted to drive a motor vehicle is 0.02%. Therefore, in the current study, all individuals with BACs below 0.02% were categorized as 'sober' control participants. With the intoxication levels of the Read et al. (1992; cf supra) study in mind, persons with BACs between 0.02% and 0.11% were categorized as 'moderately intoxicated', and participants with BACs of 0.11% or higher were classified as 'severely intoxicated'. With these criteria, there were 25 sober, 34 moderately intoxicated, and 15 severely intoxicated participants. Mean BACs in these groups were 0.00% ($SD = 0.01$), 0.06% ($SD = 0.02$), and 0.17% ($SD = 0.04$), respectively.[8]

Table 1 summarizes participants' self-reported drinking behaviour. As can be expected, participants with higher BACs were more frequent drinkers. Accordingly, more alcoholic beverages were reported to have been consumed on the night of testing as intoxication levels rose ['drinks today'; $F(2, 59) = 24.02$, $p < 0.001$, $\eta_p^2 = 0.46$]. Table 1 also summarizes pairwise comparisons between the three groups. As can be seen, for 'drinks today', all pairwise comparisons were significant. In addition, groups differed significantly from each other with respect to the number of drinking nights they reported in an average week [$F(2, 73) = 12.79$, $p < 0.001$, $\eta_p^2 = 0.35$] and the number of drinks they had on an average drinking occasion [$F(2, 73) = 15.98$, $p < 0.001$, $\eta_p^2 = 0.25$]. Thus, the number of drinking nights and the number of drinks that were reported were higher when intoxication levels were higher.

Table 1 also shows that a greater proportion of participants in both intoxication groups reported to have had a blackout experience as compared with (nearly) sober controls [$X^2(2) = 15.16$, $p < 0.001$].

Correlational approach

To test a dose–response relationship between intoxication level at encoding and memory performance, Pearson correlations were calculated between BACs, memory completeness, and memory accuracy. In line with our expectations, significant negative correlations were found between BACs and memory completeness for both total free recall ($r = -.57$, $p < 0.001$) and total cued recall ($r = -.43$, $p < 0.001$). Higher BACs were related to fewer correctly recalled central ($r = -.58$, $p < 0.01$) as well as peripheral ($r = -.30$, $p < 0.01$) details in the free recall test. The same pattern of correlations between BACs and memory performance was evident for the cued recall test ($r = -.44$, $p < 0.001$ and $r = -.34$, $p = 0.003$ for central and peripheral details, respectively). No significant correlations were found between BACs and errors during the free recall test. However, in the cued recall test, significant positive correlations were found between BACs and commission errors ($r = .29$; $p = 0.012$) and BACs and distortion errors ($r = .29$; $p = 0.013$).

A significant negative correlation was found between BACs and memory accuracy on free recall total scores ($r = -.31$; $p < 0.01$) but not with accuracy of free recall of

[7] One outlier (BAC of 0.35%) was excluded from further analyses.
[8] Because blackouts can be expected to occur with BACs of 0.15% and higher, we also carried out analyses using this criterion to define the severely intoxicated group. We found a similar pattern of findings. We prefer the cut-off of 0.11% to define severe intoxication because this corresponds to the levels in previous studies (e.g. Read et al., 1992).

Table 1. Self-reported drinking behaviour, number of alcoholic beverages consumed at time of testing (drinks today), BACs at testing, and experience with blackouts in sober, moderately intoxicated, and severely intoxicated groups. Standard deviations appear within parentheses

Mean	Sober ($n = 25$)	Moderately intoxicated ($n = 34$)	Severely intoxicated ($n = 15$)
Drinks today (SD)	1.17 (1.27)*,**,***	5.48 (3.22)	10.38 (6.52)
Drinking nights per week (SD)	1.48 (1.23)*,**	2.76 (1.07)	3.47 (1.19)
Drinks per occasion (SD)	3.32 (2.65) *,**	6.69 (3.68)	8.53 (3.70)
BACs	0.00 (0.01)*,**	0.06 (0.02)***	0.17 (0.04)
Blackout experiences (%)	20*,**	65	73

*$p < 0.05$ between sober and moderately intoxicated group.
**$p < 0.05$ between sober and severely intoxicated group.
***$p < 0.05$ between moderately and severely intoxicated group.

central or peripheral details ($r = -.10$ and $r = -.04$, respectively, both $ps > 0.40$). For cued recall, significant negative correlations were found between BACs and memory accuracy for total recall ($r = -.49$; $p < 0.001$), recall of central details ($r = -.50$; $p < 0.001$), and recall of peripheral details ($r = -.36$; $p < 0.001$).

Group differences in free recall: Completeness

Table 2 gives proportions of correctly recalled central and peripheral details as well as number of commission and distortion errors of sober, moderately intoxicated, and severely intoxicated participants during the free and cued recall test. In keeping with the concept of alcohol myopia, we expected that higher levels of intoxication would impair memory of peripheral details to a greater extent than memory of central details.

A repeated measurement ANOVA performed on the free recall data, with group (sober, moderately intoxicated, severely intoxicated) as a between-subjects factor and type of detail (central versus peripheral) as a repeated measure, revealed a significant interaction of intoxication and type of detail: $F(2, 71) = 12.50$, $p < 0.01$, $\eta_p^2 = 0.26$. As can be seen in Table 2, the level of intoxication affected recall of central and peripheral details differently.

To break down this interaction, univariate follow-up ANOVAs with group as a between-subjects factor were carried out for central and peripheral details separately. Significant between-group differences were found for central details [$F(2, 73) = 18.64$, $p < 0.001$, $\eta_p^2 = 0.34$]. Both moderately and severely intoxicated participants recalled significantly fewer correct central details compared with sober participants [both $ts > 4.25$, both $ps < 0.01$, Cohen's $ds > 1.38$]. In addition, severely intoxicated participants recalled fewer correct central details than did moderately intoxicated participants [$t = 3.30$; $p = 0.013$, Cohen's $d = 1.69$]. For peripheral details, only severe intoxication undermined correct recall when compared with sober controls [$t = 2.66$, $p = 0.05$, Cohen's $d = 0.77$].[9]

Group differences in free recall: Accuracy

Table 3 shows accuracy scores for total, central, and peripheral details of sober, moderately intoxicated, and severely intoxicated participants on the free and cued recall test. We hypothesized that increased levels of intoxication would reduce memory accuracy due to lower levels of correct details and more errors.

No significant group differences were found for the number of commissions or distortion errors that participants made during free recall [both $Fs < 1.18$, both $\eta_p^2 < 0.03$]. A repeated measurement ANOVA was conducted with group (sober, moderately intoxicated, severely intoxicated) as a main factor and type of detail (central versus peripheral) as a repeated measure for accuracy on the free recall.[10] No interaction was found between level of intoxication and type of detail [$F(2, 54) < 1.0$, $\eta_p^2 = 0.01$]. A main effect was found for type of detail [$F(2, 54) = 20.39$, $p < 0.01$, $\eta_p^2 = 0.27$] but not for group [$F(2,54) < 1.0$, $\eta_p^2 = 0.01$], indicating that all groups were more accurate in their recall of central details as compared with peripheral details.

Group differences in cued recall: Completeness

No interaction was found between level of intoxication and type of detail [$F(2, 71) = 1.46$, $p = 0.24$, $\eta_p^2 = 0.04$]. Yet, main effects were found for group [$F(2, 71) = 10.42$, $p < 0.001$, $\eta_p^2 = 0.23$] and type of detail [$F(2, 71) = 217.38$, $p < 0.001$, $\eta_p^2 = 0.56$]. Follow-up Bonferroni corrected *post hoc t*-tests revealed that both intoxication groups recalled significantly fewer central and peripheral details than sober participants [both $ts > 3.0$; both $ps < 0.01$, Cohen's $ds > 0.80$]. In addition, severely intoxicated participants tended to recall fewer central and peripheral details compared with moderately intoxicated participants, but this difference was only borderline significant [$t = 2.24$; $p = 0.07$, Cohen's $d = 0.65$]. As can be seen in Table 2, all participants recalled more central details than peripheral details.

Group differences in cued recall: Accuracy

There was a marginally significant group difference for the number of distortion errors [$F(2, 74) = 2.89$, $p = 0.06$, $\eta_p^2 = 0.08$]. This difference was only evident when comparing sober controls with severely intoxicated participants [$t = 2.38$; $p = 0.05$, Cohen's $d = 0.77$], with the latter making more distortion errors.

[9] To examine whether group differences were affected by drinking history rather than BACs at the time of testing, all data were re-analysed by including drinking behaviour as covariate. Basically, the same pattern of results was obtained.

[10] Accuracy scores for central or peripheral details could not be calculated for participants who did not report any specific central or peripheral details in their free recall. These participants (five sober, six moderately intoxicated, and six severely intoxicated) were coded as missing values, which resulted in subsample sizes of 20, 28, and 9 participants, respectively.

Table 2. Mean proportions of correctly recalled information and number of commission and distortion errors at free and cued recall test for the three groups. Standard deviations appear within parentheses

	Sober ($n = 25$)	Moderately intoxicated ($n = 34$)	Severely intoxicated ($n = 15$)
Free recall proportions			
Correct total	0.45 (0.12)*,***	0.35 (0.11)***	0.24 (0.11)
Correct central	0.74 (0.16)*,***	0.56 (0.16)***	0.41 (0.18)
Correct peripheral	0.14 (0.12)**	0.12 (0.09)	0.06 (0.07)
Commissions[a]	0.48 (0.82)	0.65 (0.88)	0.33 (0.61)
Distortions[a]	1.24 (1.00)	0.88 (0.81)	0.94 (0.96)
Cued recall proportions			
Correct total	0.57 (0.10)*,**	0.48 (0.14)	0.40 (0.11)
Correct central	0.73 (0.09)*,**	0.63 (0.19)***	0.52 (0.16)
Correct peripheral	0.46 (0.13)*,**	0.37 (0.13)	0.32 (0.11)
Commissions[a]	0.12 (0.44)	0.24(0.55)	0.47 (0.83)
Distortions[a]	6.08 (2.53)**	7.24 (3.11)	8.53 (4.05)

[a]Commissions and distortions are displayed in absolute numbers.
*$p < 0.05$ between sober and moderately intoxicated group.
**$p < 0.05$ between sober and severely intoxicated group.
***$p < 0.05$ between moderately and severely intoxicated group.

Table 3. Mean accuracy scores of free and cued recall and mean confidence ratings on the cued recall task. Standard deviations appear within parentheses

	Sober ($n = 25$)	Moderately intoxicated ($n = 34$)	Severely intoxicated ($n = 15$)
Free recall accuracy[a]			
Total	0.91 (0.06)	0.89 (0.09)	0.81 (0.24)
Central details	0.94 (0.06)	0.92 (0.08)	0.95 (0.05)
Peripheral details	0.78 (0.25)	0.73 (0.29)	0.69 (0.38)
Cued recall accuracy			
Total	0.80 (0.07)*,**	0.73 (0.09)	0.66 (0.12)
Central details	0.92 (0.07)*,**	0.88 (0.07)***	0.79 (0.13)
Peripheral details	0.71 (0.12)*,**	0.62 (0.14)	0.56 (0.14)
Confidence ratings[b]	3.60 (0.58)*	3.24 (0.61)	3.18 (0.65)

[a]Accuracy scores: number of correct details reported/(number of correct details reported/commissions + distortions).
[b]Confidence ratings varied between 1 (not confident) and 5 (confident).
*$p < 0.05$ between sober and moderately intoxicated group.
**$p < 0.05$ between sober and severely intoxicated group.
***$p < 0.05$ between moderately and severely intoxicated group.

A repeated measurement ANOVA yielded no interaction effect of intoxication groups and type of detail [$F(2, 71) < 1.0$, $\eta_p^2 = 0.021$]. Yet, main effects emerged for group [$F(2, 71) = 12.33$, $p < 0.001$, $\eta_p^2 = 0.26$] and for type of detail [$F(2, 71) = 170.25$, $p < 0.001$, $\eta_p^2 = 0.70$]. That is, as was true for free recall, all groups were more accurate in their recall of central details than peripheral details. Yet, Bonferroni corrected follow-up *t*-tests also revealed that groups differed significantly from each other in their recall of both central and peripheral details [all ts > 2.33, all ps < 0.02, Cohen's ds > 0.68]. Participants became less accurate in recalling both types of details when intoxication levels increased (see also Table 3).

Finally, sober participants were more confident about their answers on cued recall items compared with intoxicated participants [$F(2, 74) = 3.14$, $p < 0.05$, $\eta_p^2 = 0.08$].

DISCUSSION

The main findings can be summarized as follows: first, substantial negative correlations were found between BACs and both memory completeness and memory accuracy scores obtained on free and cued recall tests. Second, when comparing groups of sober, moderately intoxicated, and severely intoxicated participants, it was evident that both intoxication groups were less complete in their memories of the mock crime. This was true for their free recall of the mock crime and also when they had to answer specific questions about the mock crime (i.e. cued recall). In fact, intoxicated participants recalled up to 33% fewer correct central details in their free recall compared with sober controls. For cued recall, this difference was smaller but still up to 21%. Indeed, during free recall, reproduction of central details was especially undermined by intoxication. Contrary to the idea of alcohol myopia (Steele & Josephs, 1990), recall of peripheral details was affected to a lesser extent by intoxication.

Third, with respect to accuracy of crime-relevant memories, free recall accounts were not affected very much by high intoxication levels. However, on the cued recall test, alcohol intoxication negatively affected memory accuracy rates. That is, compared with sober controls, severe intoxication undermined memory accuracy for central details with 13% and for peripheral details with 15%. Finally, in line with our correlational findings that the memory-undermining effects of alcohol linearly increase with dose, we found that compared with moderate intoxication, severe intoxication depressed memory completeness and memory accuracy to a greater extent. For completeness, this was only the case for central details on both recall tasks, whereas for accuracy, this was evident for central details on the cued recall task only.

In line with our expectations, the current findings demonstrate that higher levels of intoxication (i.e. average BACs of 0.17%) resulted in poorer recall of crime details. However, this was also evident for moderate levels of intoxication (i.e. average BACs of 0.06%) where participants were 18% less complete in their free recall of central details and 10% less complete in their cued recall, compared with sober controls. In addition to being less complete, moderately intoxicated participants were nearly 10% less accurate in their cued recall of peripheral details. This is in contrast to findings reported by Read et al. (1992), who failed to find any detrimental effects of alcohol on memory performance when average BACs were 0.08%. Our field study suggests that even at dosages as low as 0.06% (range 0.02–0.11%), alcohol may undermine the amount of information that is subsequently recalled and may negatively affect the accuracy of memory reports during cued recall.

Apparently, then, at moderate levels of intoxication, not many errors are made in recalling highly salient features of the events. Yet, at higher intoxication levels, such errors become more evident, resulting in reduced accuracy rates in recalling central details of the event on a cued recall task.

By and large, our findings are difficult to reconcile with the idea of alcohol myopia (Steele & Josephs, 1990; Dysart et al., 2002). According to this idea, alcohol intoxication restricts the range of cues that is processed in a particular situation because attention is focussed on immediate ‘central’ cues at the expense of less important ‘peripheral’ details. This reduced capacity to attend to peripheral details would subsequently result in poorer memory for peripheral details and relatively spared memory for the salient features of the event. We found, in contrast, that both groups of intoxicated participants were far less complete in their recall of central details compared with sober controls. For peripheral details, these group differences were much smaller and even failed to attain significance when comparing moderately intoxicated participants with sober controls in their free recall. Thus, intoxication seriously affects encoding of salient features. For example, some intoxicated participants in our field study failed to recall some of the most salient items (e.g. the laptop computer that was stolen) even when they were specifically asked for it in a cued recall. Also, some participants who were severely intoxicated at the time of watching the video footage distorted central features when they were sober again and when cued about the video footage. For example, they claimed that the perpetrator entered the house using a crowbar when it was a lock pick, or they claimed that they had to force open the lock of the bike they wanted to steal, whereas the bike did not have a lock. These are all examples of distortions that undermine the type of accuracy that is relevant to police investigations.

Two explanations for this pattern of findings suggest themselves. One is that participants who distorted such details had no memory whatsoever of some of the stolen items (i.e. fragmentary blackouts) and fabricated details to please the experimenter (e.g. they mentioned a stolen mobile phone, although in fact it was a laptop computer). Another explanation is that participants confused elements of the things they had seen in the video footage with other memories of similar events (e.g. when they claimed that the laptop was on a desk rather than on the dining table, because computers usually are on desks, or when they claimed that they had to open the lock of the bike, because most bikes have locks). This explanation refers to so-called source-confusion errors (Johnson, Hashtroudi, & Lindsay, 1993).

Whereas our field findings demonstrate that many of the memory-undermining effects of alcohol occur even at relatively moderate BAC levels, they also show that relatively high levels of intoxication do not produce full-blown blackouts. Little is known about the BAC levels at which such drastic memory effect may occur. Thus, for example, Ryback (1970) speculated that at BACs as low as 0.15% blackout phenomena may occur. Our data show that this level is probably too low to produce these effects, at least with participants in a field study who are exposed to meaningful and criminally relevant stimuli. In our study, even participants with BACs far above that level did not exhibit *en bloc* amnesia for the footage.

Several limitations of the current field study deserve comment. Firstly, we showed that there is a solid link between alcohol dosage and memory performance, but our study is silent about the causal path that is involved in this link. Thus, for example, it might be the case that participants in the highly intoxicated group also had reduced intelligence levels and that this operated as a third variable. On the other hand, covariate analyses performed on our data did show that drinking history did not explain our results. This speaks to the solidity of an explanation of our findings in terms of acute alcohol intoxication rather than chronic alcohol use. Nevertheless, future studies on alcohol and memory should look at the causality issue more closely. However, from a more practical perspective—e.g. in the context of police interrogations—it may not matter why individuals who were highly intoxicated at the time they were involved in a criminally relevant event exhibit poor memory performance when they are subsequently interviewed about this event. Our field study illustrates that the poor memory of such individuals is substantial and genuine (e.g. cannot be accounted for in terms of feigning; see also Van Oorsouw & Merckelbach, 2010).

A second limitation is that we did not control for expectancy effects. Several studies have demonstrated that expectancies about the memory effect of alcohol or other drugs can affect memory performance (Kvavilashvili & Ellis, 1999; Van Oorsouw & Merckelbach, 2007). For example, Hartzler and Fromme (2003) demonstrated that participants who were familiar with the phenomenon of alcohol blackouts had stronger outcome expectancies for a range of alcohol effects and poorer memory performance both during and after intoxication. These authors argue that expectancies that individuals have about alcohol effect may affect their retrieval efficiency on a memory task. In our study, severely intoxicated participants more often reported previous blackout experiences than the other participants. Nevertheless, covariance analyses showed that previous blackout experiences did not affect memory performance on free or cued recall tasks. Meanwhile, we admit that there probably exist other individual difference factors related to alcohol expectancy effects and that may modulate the link between alcohol and memory (e.g. Abbey, 2006; Davis, Hendershot, George, Norris, & Heiman, 2007; Davis et al., 2010). Therefore, future studies should include questionnaires tapping not only alcohol-related expectancies (e.g. the comprehensive Effects of Alcohol Questionnaire; Fromme, Stroot, & Kaplan, 1993) but also traits like sensation seeking (Davis et al., 2010).

A third limitation has to do with our stimulus material. Although it was complex and meaningful and in that sense ecologically valid, the degree of involvement that it required was relatively low. Due to practical limitations, it was impossible for us to organize a staged crime in the bars that we included in our field study. Also, studies looking into the effects of feigning amnesia for a mock crime have demonstrated that memory for an enacted event was impaired to a similar extent as memory for a witnessed event (Christianson & Bylin, 1999; Van Oorsouw & Merckelbach, 2004). Nevertheless, we cannot rule out that our video footage was suboptimal in some respects, for example, in the arousal that it elicited in participants. For example, Read et al. (1992) demonstrated that arousal may reduce the memory-undermining effect of alcohol. It is likely that arousal is higher during an enacted event than during an event that is only presented on a computer screen. Therefore, it would be informative if future field studies on alcohol and memory would use a mock crime approach in which participants play an active role.

A fourth limitation of our study is that we did not control for strategic behaviour during free recall. Compared with the cued recall task, group differences for memory completeness were smaller for free recall, and they were absent for free recall accuracy. This may have been caused by strategic responding of participants during free recall. That is, participants may have used broad categories, especially for peripheral details, so as to avoid errors. Thus, overall, free recall of peripheral details was poor, and few errors were made. This may have induced floor effects in free recall accuracy. Although free recall tasks are more sensitive to such strategic behaviour than cued recall tasks, future studies might want to consider a better scoring device for free recalls. On a related note, explicit encouragement of participants to report to the best of their abilities could prevent floor effects.

It would also be informative if future field studies would test memory during intoxication as well. Some authors have argued that in lab studies, alcohol impairs long-term memory rather than short-term memory (e.g. White, 2003). Whether this can be replicated in field studies that rely on highly intoxicated participants who are exposed to meaningful material bears relevance to practical issues (e.g. police interrogations of intoxicated defendants; Evans et al., 2009). Perhaps, acutely intoxicated participants who are asked for an immediate recall of the events may have a more complete and accurate memory record than participants who were intoxicated and are interviewed after a period of 2 or 3 days. Similarly, it would be interesting to investigate how alcohol intoxication and its memory-undermining consequences contribute to suggestibility and *post hoc* misinformation effects. The results of the present study would lead one to expect that participants who have difficulties in reconstructing what happened during intoxication are highly sensitive to the cues and misinformation that others provide. It may well be the case that this underlies Gudjonsson, Hannesdottir, Petursson, and Bjornsson's (2002) finding that suggestibility levels are higher while in detoxification. On the other hand, Santtila, Ekholm, and Niemi (1999) reported that individuals who are interrogated whilst intoxicated are less sensitive to suggestive questioning compared with sober controls. Clearly, these are important areas for follow-up research.

Taken together, the findings of the present study demonstrate that even at moderate levels of intoxication, memory of crime-relevant information is suboptimal. Compared with sober controls, individuals who had been intoxicated at the time of witnessing a criminally relevant event omitted a substantial proportion of information. This was true for free recall and also when subjects were specifically asked for details. These results suggest that alcohol impairs memory encoding to a nontrivial degree. In addition, our finding that severely intoxicated individuals sometimes came up with memories that were completely erroneous (e.g. 'I forced open the bike lock to steal the bike') deserves special interest. Research on false confessions has shown that certain vulnerability factors (e.g. low IQ and mental retardation) may put interviewees at risk for false confessions (Redlich & Goodman, 2003). Our field study suggests that intoxication may also render suspects more susceptible to false statements, precisely because they have a poorer memory record of what really happened.

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