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Received: 26 April 2018 | Revised: 5 April 2019 | Accepted: 8 April 2019

DOI: 10.1002/acp.3561

SPECIAL ISSUE ARTICLE

WILEY

Alcohol intoxication impairs eyewitness memory and increases suggestibility: Two field studies

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Summary

Two field studies tested the effect of alcohol intoxication on memory for a live interaction at immediate, delayed, and repeated testing. In Study 1 (N = 86), one researcher presented bar tenants with (misleading) questions regarding a preceding interaction with another researcher. One week later, participants' memory was tested again. Study 2 (N = 189) added a delayed-testing only condition. We hypothesized intoxication to impair memory and enhance suggestibility and explored whether time of testing affected the outcome on these variables. In Study 1, intoxication reduced completeness and increased suggestibility. In Study 2, intoxication reduced completeness and increased suggestibility in delayed-only and repeated testing, compared with immediate testing. Sober participants benefited from repeated testing in Study 2, but not Study 1. Findings lend support for consolidation and decay theory and suggest that immediate (intoxicated) testing is preferable over delayed-only testing. Findings provide little support for alcohol myopia theory.

KEYWORDS

alcohol myopia, consolidation, memory accuracy, memory completeness, misinformation acceptance

1 | INTRODUCTION

Witnesses of crimes are frequently under the influence of alcohol (Evans, Schreiber Compo, & Russano, 2009; Haggard-Grann, Hallqvist, Langstrom, & Moller, 2006; Palmer, Flowe, Takarangi, & Humphries, 2013) and often still intoxicated when interviewed about the crime (Van Oorsouw, Merckelbach, & Willems, 2013). Although police officers are aware of the risks of interviewing intoxicated witnesses, in many countries (e.g., United States, Netherlands), there is no clear protocol on how to deal with these individuals (Evans et al., 2009; Van Oorsouw et al., 2013). For example, there is no policy on when to interview an intoxicated witness, immediately or after sobering up. It is the objective of the present set of two field studies to shed more light on this issue.

The main aim of the current paper was to test the effect of intoxication on eyewitness memory performance at immediate (intoxicated or sober), repeated (sober), and delayed-only (sober on first delayed test) testing. To this end, we investigated the usefulness of three theories that make opposing predictions about the optimal time to question (previously) intoxicated witnesses: consolidation theory, decay theory, and reminiscence theory. A second aim of this paper was to test a fourth theory: alcohol myopia theory (AMT), which claims that intoxication

We thank Steffie Bekkers, Nikki van Ewijk, Lotte de Geus, Nikki Gerits, Lisanne Hoetmer, Stella Lemmens, Beatrice Roddi, Relinde Rutten, Vicky Thoolen, Alexandra Wielitsch, and Maud Wouters for their help with data collection.

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affects how attention is allocated (i.e., to more central details), thereby affecting which details are encoded and recalled. Finally, we aimed to examine how alcohol intoxication affects the risk of misinformation acceptance or suggestibility and whether this risk is related to the discrepancy detection problems resulting from poor memory due to intoxication.

1.1 | Intoxication and time of testing

Drawing from different fields of research, opposing predictions can be derived on the performance of individuals intoxicated during encoding. First, consolidation theory refers to the mechanism needed to stabilize a memory trace by transfer to and storage in long-term memory (Dudai, 2004; Lee, Roh, & Kim, 2009). This process includes synaptic consolidation and network consolidation. More specifically, alcohol disrupts synaptic consolidation of memories after encoding via impaired protein synthesis in the hippocampal synapses (Söderlund, Parker, Schwartz, & Tulving, 2005; Verster, Van Duin, Volkerts, Schrueder, & Verbaten, 2003; White, 2003). Disrupted synaptic encoding leads to poor network consolidation indirectly affecting retrieval. More simply, what has not been consolidated cannot be retrieved, whether the person is still intoxicated or not. Although not much support has been found for alcohol to directly affect retrieval processes irrespective of state at encoding (Birnbaum, Parker, Hartley, & Noble, 1978; Söderlund et al., 2005; Wickelgren, 1975), alcohol evidently impairs attention and concentration (Bartl, Lager, & Domesle, 1996; Maylor, Rabbitt, James, & Kerr, 1990; Tzambazis & Stough, 2000). This, in turn, may affect the amount of information that is retrieved when intoxicated, as compared with sober. Although individuals experience encoding difficulties when intoxicated, a delayed sober compared with an immediate intoxicated test, could be beneficial for individuals' retrieval capacities by means of attentional advantages and better mnemonic strategies (Lee et al., 2009; Saults, Cowan, Sher, & Moreno, 2007). One might expect such advantages only to play a role at relatively low intoxication levels when there is at least some degree of consolidation, but not full-blown amnesia. Following this line of reasoning, delayed, compared with immediate recall, might improve retrieval performance following intoxicated encoding.

The memory advantage may even be stronger on a repeated test, which relates to the second reminiscence theory. This theory states that on repeated retrieval attempts, new information can be recalled (e.g., Erdelyi, 2010; Krix, Sauerland, Lorei, & Rispens, 2015; Odinot, Wolters, & Van Giezen, 2013; Otani, Von Glahn, Goenert, Migita, & Widner, 2009). This may seem to contradict memory decay due to passage of time, but several studies have demonstrated that forgetting does not preclude reminiscence (La Rooy, Katz, Malloy, & Lamb, 2010; Scrivner & Safer, 1988). Studies have demonstrated that previously intoxicated participants showed reminiscent recall effects (Hagsand, Roos af Hjelmsäter, Granhag, Fahlke, & Söderpalm-Gordh, 2017; Van Oorsouw & Merckelbach, 2012). Thus, two successive recall attempts may produce previously unrecalled information, which can be an effect of practice (Roediger & Payne, 1982) or a beneficial effect of different retrieval attempts (Turtle & Yuille, 1994). Based on reminiscence findings, repeated testing may be most beneficial for intoxicated individuals (see also Van Oorsouw, Merckelbach, & Smeets, 2015).

Third, decay theory, claims that memory fades as a function of delay, following the traditional view of an exponential curve (Barrouillet, Bernardin, & Camos, 2004; Ebbinghaus, 1964; Kelley, 2014). Not the delay per se, but lack of rehearsal cues, interference of newly encoded information and personal relevance of the encoded information affects the level of decay (Berman, Jonide, & Lewis, 2009; when there is no rehearsal or other memorable events taking place during the delay, this may increase the level of decay). Thus, decay is not only an effect of passage of time, but is also related to the previously mentioned network encoding.

Previous findings on the effects of alcohol intoxication on witness memory and time of testing are mixed. Studies have tested memory completeness and accuracy for a critical event, whereas people were questioned in an intoxicated or sober state. Memory completeness usually refers to recall of correct elements of a predefined set of items or an event and is usually reported in proportions or in absolute number of correctly recalled items. Accuracy, on the other hand, refers to correct recall although correcting for errors (i.e., the introduction of incorrect new information or distorted information). So, one can be incomplete but very accurate, or very complete but at the same time inaccurate (see Smeets, Candel, & Merckelbach, 2004). For immediate recall conditions, one study found no effect of alcohol intoxication on correct recall or accuracy for a staged event (Schreiber Compo et al., 2012), and one reported decreased accuracy for peripheral details (e.g., there was a dart board) of an interaction, but no effect on the overall number of reported details (i.e., memory completeness; Schreiber Compo et al., 2011). In several studies, intoxication had a negative effect on memory performance. More specifically, Yuille and Tollestrup (1990) reported diminished completeness and accuracy for a staged mock crime in intoxicated as compared with sober participants. Similarly, Van Oorsouw et al., looking at offender memory, found decreased completeness (Van Oorsouw & Merckelbach, 2012) and an increased tendency to go along with suggestions for an enacted mock crime in intoxicated, but not sober individuals (Van Oorsouw et al., 2015).

Studies using delayed recall (i.e., sober testing), reported negative effects of alcohol intoxication on recall in delayed compared with immediate testing, with one exception (Hagsand, Roos af Hjelmsäter, Granhag, Fahlke, & Söderpalm-Gordh, 2013). In particular, previous intoxication decreased completeness and accuracy for a witnessed staged event in a delayed recall test (Yuille & Tollestrup, 1990). Previous intoxication also reduced description accuracy for a committed mock theft when tested after a delay (Read, Yuille, & Tollestrup, 1992). More recently, Schreiber Compo et al. (2017) demonstrated that intoxication undermined correct free and cued recall for a witnessed event after a 1 week delay, but not in an immediate recall (see also Hildebrand Karlén, Af Hjelmsäter, Fahlke, Granhag, & Söderpalm-Gordh, 2017). Six studies (including one offender memory study) looked at the effect of alcohol intoxication on repeated recall. With one exception (La Rooy, Nicol, & Terry, 2013), and depending on recall format (free vs. cued; Hagsand et al., 2017), these studies demonstrated a negative effect of alcohol on memory that persisted on the repeated test (Flowe, Takarangi, Humphries, & Wright, 2016; Hildebrand Karlén et al., 2017; Van Oorsouw et al., 2015; Yuille &

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Tollestrup, 1990). All studies demonstrated a beneficial value of a second, sober recall attempt, in line with findings of studies on repeated testing and reminiscence effects (e.g., Erdelyi, 2010; Krix et al., 2015; Odinot et al., 2013; Otani et al., 2009).

To summarize, although the findings on the effects of alcohol on memory reports to date are mixed, the database suggests a negative effect of intoxication on memory report measures and a memory-enhancing effect of repeated testing. However, most studies conducted so far do not allow for comparison of the individual contributions of memory decay, impaired delayed recall as a result of intoxication during encoding, and benefits of repeated testing (i.e., reminiscence). For such a comparison, the performance of a delayed-testing only group would need to be compared with immediate and repeated-testing groups. The two studies that did include a delayed-testing only group (Hagsand et al., 2017; Schreiber Compo et al., 2017) did not find intoxication to impair memory, but found better memory performance on an immediate as compared with a delayed-only test. This supports the predictions of decay theory.

1.2 | Alcohol myopia theory

A second aim of the current paper was to test AMT, which claims that intoxication narrows attention down to more central tails at the cost of peripheral details. During intoxication, information is encoded more superficially—due to a lack of rehearsal, poor attention, and poor visual information processing—resulting in weaker memory traces, even at moderate intoxication levels (Hartzler & Fromme, 2003; Lee et al., 2009; Saults et al., 2007). According to AMT, when intoxication levels rise, one can only attend to a limited amount of information (Steele & Josephs, 1990). That means that attention is limited to central details (e.g., hair color of target) at the cost of peripheral details (e.g., phone on bar). Schreiber Compo et al. (2011) demonstrated AMT effects in a laboratory study. That is, compared with sober controls, moderately intoxicated participants displayed poorer memory on a written free recall test for peripheral, but not central details regarding an interaction with a bar tenant (Schreiber Compo et al., 2011). However, attempts to apply this idea to the interviewing context using a (spoken) free recall test did not result in the predicted pattern of results (Crossland, Kneller, & Wilcock, 2016; Flowe et al., 2016; Harvey, Kneller, & Campbell, 2013; Sauerland & Sporer, 2011; Van Oorsouw & Merckelbach, 2012). Rather, intoxication reduced performance also, or exclusively, for central details when compared with less central details. Hence, the second aim of the present study was to test whether alcohol, as predicted by AMT, only impacts memory for peripheral details or whether in line with more recent findings it affects also (or only) central details.

1.3 | Intoxication and misinformation acceptance

One study showed that when memory is impaired due to intoxication, people are more prone to accept misinformation (Van Oorsouw et al., 2015), whereas others found the opposite (Gawrylowicz, Ridley, Albery, Barnoth, & Young, 2017; Santtila, Ekholm, & Niemi, 1999), no effect (Schreiber Compo et al., 2012), or mixed results (Garfinkel, Dienes, & Duka, 2006). According to the discrepancy-detection principle (Peterson, Rothfleisch, Zelazo, & Pihl, 1990; Schooler & Loftus, 1986), it becomes more difficult to detect discrepancies between one's memory for an event and suggested details when memory for the original event is poor. In line with this idea, Van Oorsouw et al. (2015) demonstrated that the relationship between level of intoxication and suggestibility was mediated by memory performance. So, when intoxicated individuals had poor memory of the crime, they became more suggestible. According to Schreiber Compo et al. (2012), who did not find evidence for increased misinformation acceptance, the susceptibility to accept misinformation may depend on event salience. That is, participants may be less inclined to go along with suggestions about better, centrally encoded, details. The two other studies that did not find increased suggestibility in intoxicated participants (Gawrylowicz et al., 2017; Santtila et al., 1999) had a different design. More specifically, the authors intoxicated participants after they had encoded the critical event about which they later were presented with misinformation. That means that memory was not impaired due to intoxication, and the tendency to go along with suggestions could not be an effect of poor memory, but rather a result of retrograde facilitation of memory through alcohol consumption. This rules out poor encoding as an explanation for increased suggestibility following intoxication and leaves discrepancy detection as a valid theorem for misinformation acceptance in the current studies.

1.4 | The present studies

To summarize, the present studies further examine the relation between intoxication and time of testing and to inform about the best moment for interviewing a (previously) intoxicated witness. Therefore, we conducted two field studies. The first study served to replicate the beneficial effects of repeated testing reported earlier (Hagsand et al., 2017; Van Oorsouw et al., 2015; Yuille & Tollestrup, 1990), using an eyewitness paradigm. Bar patrons were subjected to a staged interaction on a night out. This setting enabled us to test participants in a real life setting with a wide range of naturally occurring intoxication levels. Participants completed a memory test including a suggestibility check immediately following the staged interaction, and again after a delay of several days. Study 2 employed a repeated testing (immediate and delayed recall), and a delayed-testing only group. This design allowed us to test whether immediate recall would be beneficial for intoxicated participants as compared with delayed recall where encoding defects and decay effects play a role. The role of intoxication on event salience and susceptibility to misinformation were tested by scoring for central and peripheral details separately and by including suggestive memory questions.

1.5 | Hypotheses and predictions

The first aim, to test when best to question an intoxicated person about an event, included the test of several hypotheses based on the theories described earlier. Consolidation theory predicts poor encoding during intoxication, resulting in poor recall both immediately

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and on a sober (repeated or delayed) test. This would predict a main effect of blood alcohol concentration (BAC) on memory completeness and accuracy (Hypothesis 1a; Studies 1 and 2). However, the reminiscence account predicts an effect of time of retrieval, with better performance on a (within subjects repeated) sober test compared with only an immediate, intoxicated test (Hypothesis 1b; Studies 1 and 2). This is because the information is repeatedly retrieved and therefore rehearsed. For immediate versus delayed-testing only (between subject), decay theory predicts an advantage for immediate testing due to memory decay over time (Hypothesis 1c; Study 2).

The second aim of the paper was to test AMT. AMT predicts a main effect of BAC on peripheral but not central details (Hypothesis 2; Studies 1 and 2).

The third aim of this paper was to investigate whether intoxication results in a higher tendency to adopt misinformation, and whether this is mediated by reduced memory performance (i.e., discrepancy detection problems). We expected intoxication to increase misinformation acceptance (i.e., a main effect of BAC; Hypothesis 3a) and memory completeness to mediate misinformation acceptance; i.e., poor memory would then result in more misinformation acceptance (Hypothesis 3b), as predicted by the discrepancy detection principle.

An overview of all hypotheses and expected outcomes can be found in Table 1.

2 | FIELD STUDY 1

2.1 | Method

2.1.1 | Participants

Eighty-six students and community members (40 women; M_{age} = 22.9, age range: 18–44 years, *SD* = 5.11) took part in Session 1.[1] All were Caucasian,[2] as were the researchers (all female, aged 21 years). On average, women consumed fewer drinks on the test night and had lower BAC levels than men (2.3 vs. 6.8 drinks; BAC: 0.023 $p < .001$, vs. .050; $p = .001$). Overall, women drank less than men on an average night out (6.1 vs. 9.3 drinks, $p = .017$). There were no differences in reported blackout rates between men and women ($p = .715$). Male participants were significantly older than female participants (24.5 vs. 21.1 years, $p = .001$). Forty-five participants also responded to the online follow-up session, and were thus tested repeatedly. Both field studies were approved by the standing ethical research committee of the faculty.

[1]Sample size was estimated based on medium effect sizes reported in previous studies (e.g., Flowe et al., 2016; Schreiber Compo et al., 2012; Van Oorsouw et al., 2015; Van Oorsouw & Merckelbach, 2012) using ANOVA. Retrospectively, more advanced statistics (generalized estimating equation) for which no power packages are available, were used to increase power and avoid attrition.

[2]To prevent cross-race bias, only Caucasians were approached.

2.1.2 | Design

BAC in Session 1 served as a continuous predictor and test session (immediate vs. repeated) as within subjects factor. The dependent variables were memory completeness, memory accuracy, and the tendency to adopt misinformation.

2.1.3 | Operationalization of dependent variables

Memory scoring

The test of participants' memory for the interaction with the researcher consisted of 10 questions, of which five were memory questions (two open and three cued) and five were misinformation questions administered orally. The items can be found in Appendix A. Questions were based on previous work (Van Oorsouw et al., 2015; Van Oorsouw & Merckelbach, 2012) and the Gudjonsson Suggestibility Scales (Gudjonsson, 1997). The questionnaire started with the two open questions, asking for a detailed description of the conversation participants had with the researcher and the appearance of the researcher. The cued and misinformation questions were presented in a mixed fashion. For the five memory questions, a coding protocol containing 19 critical information units was used to code participants' answers. These units referred to descriptions of the interaction with the researcher (e.g., what she looked like, what she held in her hand, and what she said).

To test AMT, memory accounts were scored also for central and peripheral details separately. Nine information units pertained to central details and 10 to peripheral details. Different definitions of central versus peripheral have been used in previous research. In staged interactions used in alcohol myopia research (e.g., Crossland et al., 2016; Flowe et al., 2016; Schreiber Compo et al., 2011; Van Oorsouw & Merckelbach, 2012), elements related to the crime or perpetrator were coded as central, whereas surroundings were considered peripheral details. When defining centrality of emotional events, distinctions have been made between thematic centrality (Heuer & Reisberg, 1990) and visual centrality (Christianson & Loftus, 1991). Because the event in the present study was not particularly emotional, we used the thematic coding as described by Heuer and Reisberg (1990). More specifically, we defined as central such details that cannot be changed without changing the basic story or its sequence. This means that the main actions, appearance of the target, and biographical information relevant to the story were coded as central. Because the target was also visually central (Christianson & Loftus, 1991), details related to the target were also coded as central (cf. Flowe et al., 2016; Schreiber Compo et al., 2011, for a similar approach). Central details included the following: she asked me what bar was open late, she asked for directions, her phone rang, something bad happened, she mentioned an ambulance, and she had blonde hair, a big purse and a huge scarf around her neck, no glasses. Peripheral details are those details that do not change the story line if they were recalled differently (Heuer & Reisberg, 1990). Peripheral details included the following: she said she was not from here, she told me she came from Eindhoven, she asked whether this bar closes at 2 pm, she took from her purse a pack

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TABLE 1 Overview of predictions and outcomes for each dependent measure for two field studies

					Study 1 immediate vs. repeated		Study 2 immediate vs. repeated		Study 2 immediate vs. delayed	
	Hypothesis	Dependent variable		Expected outcome	Observed outcome	H1 confirmed?	Observed outcome	H1 confirmed?	Observed outcome	H1 confirmed?
1a	Consolidation	Completeness		BAC	BAC trend	✓ partly	BAC × Session	✓partly		
		Accuracy		BAC	ns	✘	BAC × Session	✓partly		
1b	Reminiscence/ optimal retrieval	Completeness		Session (1 < 2)	ns	✘	BAC × Session Sober: 1 < 2* Intox: ns*	✓partly		
		Accuracy		Session (1 < 2)	ns	✘	BAC × Session Sober: ns* Intox: 1 > 2*	✘		
1c	Decay	Completeness		BAC Session (1 > 2)					BAC Session: 1 > 2	✓
		Accuracy		Session (1 > 2)					skewed	-
2	Alcohol myopia theory	Completeness	Central	no BAC	BAC	✘	BAC × Session Immediate: BAC effect*	✘	BAC Session: 1 > 2	✘
		Accuracy		no BAC	BAC	✘	Delayed: BAC effect (stronger than immediate)*	✘	skewed	-
		Completeness	Peripheral	BAC	ns	✘	BAC Session: 1 < 2	✓	BAC Session: 1 > 2	✓
		Accuracy		BAC	ns	✘	BAC × Session No BAC effect on either session*	✘	skewed	-
3a	Discrepancy detection	Misinformation acceptance		BAC	BAC Session: 1 > 2	✓	Session: 1 < 2	✘	BAC × Session Immediate: ns* Delayed: Intox > sober*	✓ partly
				Mediated by completeness	Mediated by completeness	✓	ns	✘	Mediated by completeness	✓

Note. * signifies simple slopes effect. ✓ = hypothesis supported; ✘ = hypothesis not supported. ns = not significant. Intox. = intoxicated participants.

Abbreviation: BAC, blood alcohol concentration.

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of cigarettes and a phone, the conversation lasted about 2 min, she took off in an emergency, color bag, color scarf, and hair in ponytail.

Memory completeness was computed by dividing the number of correct answers concerning the critical information units by the maximum obtainable score for the total score and for central and peripheral details (cf. Smeets et al., 2004). No points were earned for "don't know" answers, resulting in a lower completeness score.

Memory accuracy for total scores and central and peripheral details was calculated by dividing the number of correctly recalled details by the total number of recalled details (including commissions and distortions; see Krix, Sauerland, Gabbert, & Hope, 2014; Smeets et al., 2004, for a similar procedure). Distortion errors refer to pieces of information that were essentially correct but misrepresented during the memory test. For example, "the woman was carrying a blue bag," when she was carrying a green bag. Commission errors were defined as the introduction of new, false information (e.g., "the woman was wearing a hat" when she was not). Recall performance was coded by the first author and an independent rater who were both blind to intoxication levels. Pearson's correlations between the two raters for the number or correctly recalled details and errors were large, *r*s $\geq$ .83, (*p*s < .010).

Misinformation acceptance

Participants' acceptance of misinformation was tested by including five misinformation items about the target in the memory test. These were all false alternative questions. For example, the question mentioned the type of drink she was holding when in fact she was not holding a drink. The score ranged from 0 to 5, with a higher score indicating a higher tendency to go along with suggested misinformation.

2.1.4 | Procedure

Participants were approached by Researcher 1 in local bars between 10 pm and 2 am. To make sure that the researchers were not noticed by potential participants, only a few participants, standing apart from each other, were tested in each bar at each test night.

During a practiced, approximately 90-s long conversation, Researcher 1 told the participant that she was from out of town and asked for location and clubbing suggestions (i.e., "Hello, I'm not from here, I'm from Eindhoven, this bar closes at 2 pm, right?, What bar is open after that?, How do I get there?"). One minute into the conversation, the researcher received a phone call from Researcher 2. She made sure that the participant heard that it was about an emergency involving an ambulance (i.e., "Oh my god, are you all right? Did they call an ambulance? I am on my way."). This was done to increase arousal in the situation, but also to introduce a memorable subject that we could ask questions about later on. After hanging up, Researcher 1 excused herself due to the emergency (i.e., "Sorry, I have to go, there is something with my friend."). Participants were then immediately approached by the second researcher who informed them that they had taken part in an experiment. With written consent provided, participants were taken to a separate room where their breath alcohol concentration (BrAC) was measured, using the Dräger Alcotest 6510.[3] It converts the BrAC into BAC by the use of a breath-to-blood conversion factor known as the blood/breath ratio (Jones, 2000). Participants were not informed about their BrAC level until after the follow-up session (see details about this session below). Estimated from practice sessions in which within-researcher variation was small, this interaction also lasted about 90 s. Next, Researcher 2 left the room and a third researcher entered and questioned participants about their drinking habits, drinking behavior on that particular evening, and comorbid drug use.[4] After that, participants were presented with a photo lineup concerning Researcher 1 (i.e., identification test). The position of Researchers 1, 2, and 3 in the sequence was counterbalanced. The lineup data were collected to investigate the effects of alcohol on identification performance. The complete lineup data are reported elsewhere (Sauerland, Broers, & Van Oorsouw, 2019). Next, participants filled in the 10-item memory and misinformation test described earlier that asked them about the conversation and the person they spoke to (see Appendix A). The memory questions mostly pertained to the conversation and target features and not to the appearance of the researcher with whom they had the conversation (e.g., type of bag she carried and clothing she wore).[5] The reason for this was to prevent verbal overshadowing by asking participants to give a description of the face, which in turn may affect face identification on the follow-up identification task (Meissner & Brigham, 2001). The time to complete the two tasks was unlimited. Finally, participants were thanked and informed that they would be contacted via e-mail for a follow-up within one week.

The follow-up consisting of the same 10-item memory and misinformation test were distributed via e-mail. Participants were instructed to only reply to the e-mail when sober. Following a "yes" response, they were first given access to the memory test and then the lineup. Upon completion, participants received a thank-you e-mail containing their BAC level during Session 1 and were fully debriefed. No monetary or other compensation was offered.

3 | RESULTS AND DISCUSSION

3.1 | Statistical analyses

3.1.1 | Treatment of dependent data

Of the 86 participants that were approached, all consented to participate in Session 1. Forty-five responded to our e-mail invitation to

[3]To reduce the risk of erroneously high readings, we had every participant rinse their mouth with water before taking the breathalyzer test.

[4]None of them had used illicit drugs.

[5]Except for Question 2 (see Appendix A) that also scored correct hair color and style. To check whether the picture presentation affected memory performance preliminary analyses were conducted. These demonstrated that there was no relation between any of the memory performance measures (completeness, accuracy, misinformation acceptance) and identification accuracy (all *r*s < 0.11, all *p*s > 0.05).

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participate in Session 2, of which 44 answered the memory questions.[6, 7] The presence of repeated observations means that the outcome cannot be modeled with traditional linear regression models, because both of these models assume independent residuals. We therefore resorted to generalized estimating equations (GEE; Hanley, Negassa, Edwardes, & Forrester, 2003). GEE allows the specification of a regression model with dichotomous but also continuous outcome measures and any combination of within- and between-subject factors and covariates as predictors, with the specification of so-called working correlation matrix as a nuisance parameter to accommodate the correlated residuals that result from repeated measurements. Furthermore, a specific advantage of GEE over the more traditional repeated measures ANOVA is that parameter estimates are based on all available data, where the generalized linear model procedures in SPSS respond to attrition with list-wise deletion of missing values, leading to a substantial loss of information. GEE assumes that the responses are correlated that there exists a linear relationship between the predictors in the model and a transformation of the response (through an appropriate link function, like in generalized linear models), and that the correlations between the residuals have been appropriately modeled with a working correlation matrix. For our data, we established the existence of linear relationships between the predictors and the outcome variables and ensured appropriate modeling of the correlated residuals by the specification of an exchangeable (or compound symmetry) working correlation matrix. For a repeated measures variable with only two levels (like session in our analyses), the exchangeable structure is always correct.[8]

3.2 | Blood alcohol concentrations

BACs varied between 0.00% and 0.16%, with M = 0.06% among intoxicated participants (SD = 0.042; see Figure 1). Thirty-one participants (36%) were sober, 29 (34%) were intoxicated below the drink-drive limit of 0.05% (M_{BAC} = 0.02%), and 26 (30%) had BAC levels above the drink-drive limit (M_{BAC} = 0.10%). Level of intoxication correlated positively with the number of drinks consumed during the night of testing (r = .67, p < .001), the average number of drinking nights in a particular week (r = .29, p = .007), and the average number of drinks on a particular evening (r = .22, p = .044). This indicates that the more intoxicated individuals, there were more experienced drinkers.

3.3 | Effect of BAC on memory and time of testing

Table 2 presents the mean scores for the dependent variables on both test sessions. To test how memory completeness and memory accuracy were affected by BAC and test session (immediate vs. repeated), we performed GEE analyses with BAC (as a linear measure), test session, and the BAC × Test Session Interaction entered into the model. Separate analyses for total scores (to test consolidation and reminiscence theory) and central and peripheral details (to test AMT) were conducted for memory completeness and memory accuracy (i.e., seven GEE analyses in total). Nonsignificant interaction and main effects were excluded sequentially. The final model for total memory completeness included only a marginally significant main effect of BAC, b = −0.07, Wald $\chi^2(1)$ = 3.76, p = .052, indicating that memory reports tended to be less complete for higher levels of intoxication, as compared with lower levels of intoxication, regardless of test session. For memory accuracy, no effects were found. These findings lend partial support to the consolidation theory (Hypothesis 1a) but not reminiscence (Hypothesis 1b) in that a repeated (sober) test did not improve memory.

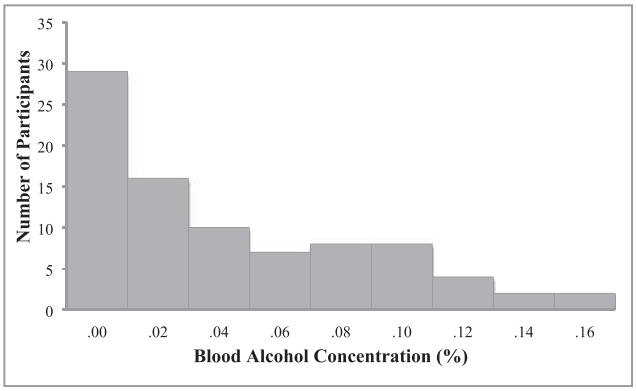


FIGURE 1 Blood Alcohol Concentration Distributions Study 1.

TABLE 2 Mean memory completeness, accuracy, and misinformation scores independent of level of intoxication (Experiment 1)

	Immediate test (N = 86)	Repeated test (N = 45)
Memory completeness (%)		
Total	0.44 (0.11)	0.48 (0.11)
Central details	0.38 (0.18)	0.43 (0.20)
Peripheral details	0.51 (0.17)	0.53 (0.14)
Memory accuracy (%)		
Total	0.85 (0.13)	0.84 (0.11)
Central details	0.77 (0.14)	0.75 (0.14)
Peripheral details	0.72 (0.32)	0.68 (0.32)
Misinformation score	2.50 (1.33)[a]	1.90 (1.39)[a]

Note. Cells sharing the same superscript letter differ at p = .05.

3.4 | BAC and AMT

AMT predicts a difference in the effects of alcohol on central and peripheral details. The final model for memory completeness concerning central details included only the significant main effect of BAC, b = −0.17, Wald $\chi^2(1)$ = 23.05, p < .001, indicating that memory

[6]Following the first session, participants responded to the memory test within 2–14 days (M = 5.2 days; SD = 3.7; 81% responded within 8 days).

[7]To assess whether response range affected memory performance, all analyses were conducted with delay (number of days) as a predictor. This factor was not predictive of any of the dependent variables and will therefore not be discussed.

[8]The data that support the findings of this study are available from the corresponding author upon reasonable request.

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reports for central details were less complete with higher levels of intoxication, compared with lower levels of intoxication, regardless of test session. For peripheral details, no statistically significant effects were found.

For memory accuracy, a similar pattern of results was found: a main effect of BAC for central, $b = -0.03$, Wald $\chi^2(1) = 9.20$, $p = .002$, but not peripheral detail accuracy, $b = -0.13$, Wald $\chi^2(1) = 0.23$, $p = .63$, was found. Thus, increasing BACs only reduced accuracy for central details, thereby disconfirming AMT (Hypothesis 2).

3.5 | BAC and misinformation acceptance.

For acceptance of misinformation, main effects for BAC, $b = 0.87$, Wald $\chi^2(1) = 9.42$, $p = .002$, and test session, $b = -0.64$, Wald $\chi^2(1) = 13.50$, $p < .001$, were found. BAC increased the acceptance of misinformation, and acceptance of misinformation was higher in the immediate, intoxicated test, as compared with the repeated, sober test. The predicted BAC effect was found (Hypothesis 3a), but the session effect was not expected.

To test whether memory completeness mediated the relationship between BAC and misinformation acceptance in accordance with the discrepancy detection principle, Pearson's correlations were calculated between BAC, memory completeness, and tendency to go along with misinformation. A significant correlation existed between BAC and memory completeness ($r = -.27$, $p = .002$) and also between BAC and the tendency to adopt misinformation ($r = .27$, $p = .002$). Multiple regression of the tendency to adopt misinformation on both BAC and memory completeness returned a significant effect of completeness, $b = -4.18$, $\beta = -0.44$, $t = -4.26$, $p < .001$, and a nonsignificant effect of BAC, $b = 0.512$, $\beta = 0.26$, $t = 1.94$, $p = .054$. According to the mediation scheme outlined by Baron and Kenny (1986), these results support the interpretation of the BAC effect on the tendency to adopt misinformation to be fully mediated by memory completeness, which is in line with discrepancy detection theory and in support of Hypothesis 3b.

Based on the regression coefficients of the significant predictor variables, we were able to estimate how alcohol intoxication affects memory. Table 3 shows how completeness, accuracy, and misinformation acceptance are predicted by increasing levels of intoxication in a dose-dependent way; rising intoxication levels are predicted to decrease completeness and accuracy and to increase misinformation acceptance. Overall, this means that memory completeness is expected to decrease about 10% at a BAC level of 0.09 and with almost 20% at a BAC of 0.21 as compared with intoxication that is still below the legal drink-drive limit. We display scores for intoxication levels with an increase of 0.03 units of alcohol per level to give an impression how intoxication affects the dependent variables from nearly sober to severely intoxicated states.

TABLE 3 Predicted outcome scores based on different BAC levels for memory completeness, accuracy, and acceptance of misinformation (Study 1)

	BAC level in percent				
	0.03	**0.06**	**0.09**	**0.12**	**0.15**
Completeness total[a]	0.45	0.43	0.40	0.38	0.36
Completeness central details[a]	0.53	0.48	0.42	0.37	0.32
Accuracy central details[a]	0.78	0.74	0.70	0.67	0.63
Misinformation acceptance[b]	2.43	2.69	2.96	3.22	3.48

Abbreviation: BAC, blood alcohol concentration.

[a]Based on BAC main effect.

[b]Based on main effect for BAC, controlling for time of testing, increase of 0.03 units of alcohol per level.

To summarize, Study 1 partially confirmed Hypothesis 1a, which predicts that alcohol intoxication impairs the consolidation of memories. Intoxication decreased (central) memory completeness but not accuracy (Hypothesis 1a). Contrary to the reminiscence theory (Hypothesis 1b; repeated testing improves memory), the effects found were not moderated by time of testing. In contrast to AMT (Hypothesis 2: BAC affects peripheral not central memory), alcohol in the present study undermined central and not peripheral memory. As predicted, intoxication increased the acceptance of misinformation (Hypothesis 3a), and more so on an immediate test. This effect was mediated by memory completeness, in line with hypothesis 3b and discrepancy detection theory, claiming that poor memory results in more misinformation acceptance.

Finding partial or no support for Hypothesis 1a (i.e., intoxication reduces memory completeness and accuracy) and 1b (i.e., repeated testing improves memory) may indicate that either the negative effect of alcohol on consolidation and the beneficial effects of sober retrieval balanced each other out or that there was a ceiling effect in the memory completeness recall data due to a limited number of items. Evidence for this comes from previous studies with a similar recall format. Here, participants without any experimental manipulation in a free recall reported around 50% of all information, and participants who received a memory manipulation (e.g., intoxication), between 25% and 35% (see Christianson & Bylin, 1999; Van Oorsouw et al., 2015; Van Oorsouw & Merckelbach, 2004, 2006, 2012). However, in the present study, the average memory completeness was already around 43%, suggesting that the use of such a limited number of items would make it difficult to detect a convincing improvement. Therefore, in Study 2, we made some changes. This was to account for police advisors' and laypersons' belief that an intoxicated witness or perpetrator should sober up before a first interview due to risks of memory errors, false confessions, and waiving of rights although intoxicated (e.g., Evans et al., 2009; Van Oorsouw et al., 2013). Consequently, Study 2 added a delayed-testing control group that was only tested after a delay. The goal of adding such a group was to investigate whether a delayed (sober) first test would indeed result in better memory performance as compared with an immediate (intoxicated) test as a result of sobering up, or whether the delay would impair memory due to the passage of time (as predicted by decay theory, Hypothesis 1c). The original repeated testing condition from Study 1 was also included to replicate the benefit of repeated testing (i.e.,

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reminiscence, Hypothesis 1b; cf. Hildebrand Karlén et al., 2017; Van Oorsouw et al., 2015; Yuille & Tollestrup, 1990). Second, because we could not find evidence for reminiscence in Study 1 due to possible ceiling effects, we increased the number of items in the memory tests in Study 2.

4 | FIELD STUDY 2

5 | Method

5.1 | Participants

One hundred ninety one students and working individuals participated in Session 1. All were Caucasian, as were the researchers. Two participants were excluded from the data file because of comorbid drug use, leaving 189 participants for analyses (97 men; M_{age} = 26.46, age range: 17–54[9] years, *SD* = 6.84). In the follow-up, 137 participants completed the memory test. Women had consumed fewer drinks on the test night (2.8 vs. 6.3 drinks; $p < .001$) and had lower corresponding BAC levels than men (0.024 vs. 0.051; $p < .001$). On average, men drank more on a general night out than women (7.0 vs. 5.0 drinks; $p = .004$). There were no differences in reported blackout rates between women and men ($p = .513$).

5.2 | Design and procedure

For the memory data, BAC served as a predictor and time of testing (immediate testing vs. delayed-testing only)[10] as a between-subjects factor. Additionally, time of testing was varied as a within subjects factor (immediate testing vs. repeated testing). In Session 1, all participants gave consent, filled in the drinking habit questionnaire, and were randomly assigned to either immediate (also repeated) or delayed-only testing groups. Ninety participants also completed the memory test (immediate testing). Of these, 70 completed the memory test again in Session 2 (repeated testing). Sixty-seven participants completed the memory test only in Session 2 (delayed testing). On the night of the event, they were told that they would be contacted within 1 week to answer some questions about this evening, similar to what all other participants were told after memory test completion.

Three experimenters were involved in this study. One of them always assumed the role of Researcher 3. The roles of Researchers 1 and 2 were counterbalanced between the remaining two experimenters.

The procedure was identical to Study 1 with the following exceptions: given the changes in the design, about 50% of the participants did not fill in the memory test in Session 1 (delayed-testing only group). For the follow-up, participants received one e-mail that contained the memory questionnaire.[11] Some details were added to the conversation and appearance. This time, Researcher 1 told the participant that she was from out of town and lost her friends who apparently went to a bar that was open late. The gist of the conversation was as follows: "Hello, I lost my friends; I'm not from here but from Eindhoven; we are visiting for a couple of days with old friends from high school; one of them got sick and they went outside; I tried to call them but they don't answer. What's the name of this bar so I can text them where I am?" The mentioning of the emergency and ambulance were similar to Study 1. The complete lineup data are again reported elsewhere (Sauerland et al., 2019).

5.3 | Memory testing and coding

Memory testing and coding was analogous to Study 1, with the exception that the questionnaire (and the conversation) was extended by several questions to prevent ceiling effects, resulting in a total of 19 questions adding up to 52 critical information units of that 24 were central and 28 peripheral. Examples of added central details were conversation details like the following: one of the friends got sick, and a large flower was added to the hair as a central detail. Examples of added peripheral details were as follows: she knew her friends from high school, they were visiting town for the weekend. Five misinformation items were added to the questionnaire, leading to a total of 10 items. Examples are similar to those described in Study 1. The questions can be found in Appendix B.[12] Pearson's correlations between the two raters for the number or correctly recalled details and errors were large, $rs \geq .81$, ($ps \leq .010$).

6 | RESULTS AND DISCUSSION

6.1 | Statistical analyses

To analyze the effect of time of testing (immediately or delayed-only; between-subjects factor) and BAC on memory completeness, accuracy, and misinformation acceptance, separate linear regression models were built for each of these dependent variables, including time of testing, BAC, and the Time of Testing × BAC interaction. Next, nonsignificant interaction and main effects were sequentially excluded from the model. In a separate analysis, we additionally examined the within group effect of repeated testing. For this analysis, we again made use of a GEE model.

[9]One participant was 17 years old at the time of Session 1, but had turned 18 years old by the time he participated in Session 2. Therefore, we kept his data in the data set.

[10]Participants responded within 4–23 days, of which 81.4% did so within eight days (*M* = 6.81 days; *SD* = 3.0).

[11]As in Study 1, identification data were collected in this study as well. In contrast to Study 1, the memory items now did not ask for a description of the target so that the line-up presentation could not affect the memory test (see Appendix B for memory test items).

[12]These items consisted of leading (four items), affirmative, and false alternative questions (three items each; for details see the GSS Manual; Gudjonsson, 1997).

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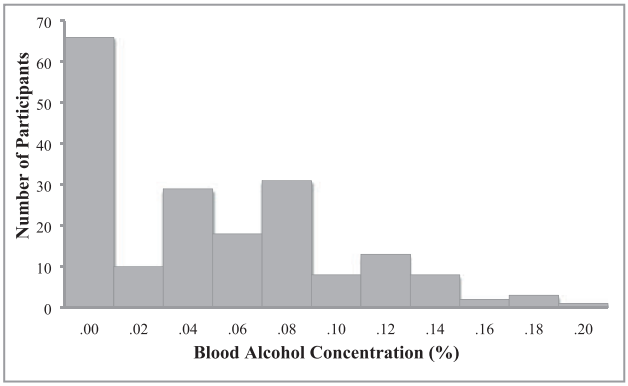


FIGURE 2 Blood Alcohol Concentration Distributions Study 2.

6.2 | Blood alcohol concentrations

BACs varied between .00% and.20% with M = 0.058% (SD = 0.04) among intoxicated participants (see Figure 2). Sixty-six participants (35%) were sober, 57 of them (30%) were intoxicated below the drink-drive limit of 0.05% (M_{BAC} = 0.02%), and 66 (35%) had BAC levels above the drink-drive limit (M_{BAC} = 0.087%). As in Study 1, the level of intoxication correlated positively with the number of drinks that were consumed at the night of testing (r = .76, p < .001), the average number of drinking nights in a particular week (r = .52, p < .001), and the average number of drinks on a particular evening (r = .18, p = .013).

6.3 | Effect of BAC on memory and time of testing

6.3.1 | Immediate versus delayed-testing only

The initial regression model included BAC, time of testing (immediate or delayed-only), and the BAC × Time of Testing interaction.[13] The final model for memory completeness, accounting for 24% of the variance, included the main effects of BAC, b = −0.11, β = −0.42, t = - 5.95, p < .001, and time of testing, b = −0.06, β = −0.28, t = −4.03, p < .001. Thus, participants were less complete when intoxicated and on the delayed test as compared with the immediate test, supporting consolidation and decay theory.

The final regression model for memory accuracy only included the significant main effect of time of testing, with memory being more accurate on an immediate than a delayed test. However, the distribution was extremely skewed with over 70% of all participants being 100% accurate, suggesting ceiling effects, and making data transformation impossible. Therefore, accuracy effects cannot be reliably reported.

[13]All analyses were also conducted with delay (number of days) as a predictor. As in Study 1, this factor was not predictive for any of the dependent variables and will therefore not be discussed.

6.3.2 | Immediate versus repeated testing

To test the potential reminiscence effect of single (immediate) versus repeated (immediate and delayed) testing within the same group of participants, a GEE model including BAC, time of testing (immediate vs. repeated), and the Time of Testing × BAC interaction was computed.

For memory completeness, a Time of Testing × BAC interaction was found, b = −0.04, Wald $\chi^2(1)$ = 4.70, p = .030. Simple slopes analyses revealed a significant time of testing effect for previously sober (BAC = 0.0%), b = 0.05, Wald $\chi^2(1)$ = 16.30, p < .001, but not for intoxicated participants, b = 0.02, Wald $\chi^2(1)$ = 3.17, p = .075. That is, sober participants were predicted to be 5% more complete on average on a repeated versus immediate test, supporting the idea of reminiscence (Hypothesis 1b).

For memory accuracy also, an interaction effect materialized, b = −0.09, Wald $\chi^2(1)$ = 4.39, p = .036. Simple slopes analyses demonstrated a significant reduction in memory accuracy on the repeated test for previously intoxicated, b = −0.06, Wald $\chi^2(1)$ = 6.69, p = .010, but not sober participants (BAC = 0), b = 0.006, Wald $\chi^2(1)$ = 0.01, p = .694. More specifically, the predicted accuracy in a previously intoxicated participant was reduced by 6% on a repeated compared with an immediate test. These findings support the idea of reminiscence, but only when intoxication levels are low. When intoxication was high, repeated testing resulted in reduced accuracy, presumably as part of decay and subsequent susceptibility to errors and misinformation.

To conclude, Study 2 suggests that a delayed-only test is not recommendable, as this seems to increase impairment associated with consolidation problems in previously intoxicated participants. Repeated testing did not decrease this effect, with only previously sober witnesses benefiting from repeated testing.

6.4 | BAC and AMT

6.4.1 | Immediate versus delayed-only testing

The final model for central memory completeness, accounting for 18% of the variance, included the main effects of BAC, b = −0.14, β = −0.38, t = −5.29, p < .001, and time of testing, b = −0.06, β = −0.20, t = −2.69, p < .010. For peripheral details, a similar pattern of results was found with BAC, b = −0.08, β = −0.33, t = −4.64, p < .001, and time of testing, b = −0.06, β = −0.31, t = −4.32, p < .001, accounting for 20% of the variance. Thus, under higher intoxication levels, memory reports were less complete, and the delayed-testing group produced less complete memory reports than the immediate testing group for both central and peripheral details, which is in contrast to what AMT suggests, but confirms what can be expected from decay theory. Table 4 displays the mean completeness, accuracy, and misinformation scores. Due to skewed distribution, central and peripheral accuracy effects will not be further reported.

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TABLE 4 Mean completeness, accuracy, and misinformation scores independent of level of intoxication (Study 2)

	Immediate test (*n* = 90)	Delayed-only test (*n* = 67)	Repeated test (*n* = 70)
Memory completeness (%)			
Total	0.26 (0.09)[a,b]	0.20 (0.11)[a]	0.29 (0.11)[b]
Central details	0.35 (0.12)[a,b]	0.29 (0.16)[a]	0.39 (0.14)[b]
Peripheral details	0.18 (0.09)[a]	0.13 (0.08)[a]	0.21 (0.11)
Memory accuracy (%)			
Total	0.95 (0.07)[a]	0.91 (0.11)[a]	0.92 (0.10)
Central details	0.97 (0.06)[a]	0.91 (0.15)[a]	0.95 (0.07)
Peripheral details	0.91 (0.12)	0.89 (0.16)	0.86 (0.19)
Misinformation score	1.60 (1.33)[a]	2.60 (1.95)[a]	1.90 (1.47)

Note. cells sharing the same superscript letter differ at $p < .01$.

6.4.2 | Immediate versus repeated testing

A significant Time of Testing × BAC interaction for central memory completeness, $b = -0.06$, Wald $\chi^2(1) = 5.64$, $p = .018$, indicates that the BAC effect was more detrimental under repeated ($b = -0.21$, Wald $\chi^2(1) = 39.57$, $p < .001$) than under immediate testing conditions ($b = -0.15$, Wald $\chi^2(1) = 28.16$, $p < .001$). No significant effects were found for central memory accuracy.

For peripheral memory completeness, in line with AMT, main effects of BAC, $b = -0.09$, Wald $\chi^2(1) = 24.95$, $p < .001$, but also time of testing, $b = 0.02$, Wald $\chi^2(1) = 6.03$, $p < .014$, were found. Completeness of peripheral details was reduced when intoxication levels increased, and more peripheral details were reported on a repeated compared with an immediate test. The significant Time of Testing × BAC interaction effect for peripheral memory accuracy, $b = -0.16$, Wald $\chi^2(1) = 5.65$, $p = .017$, showed no significant BAC

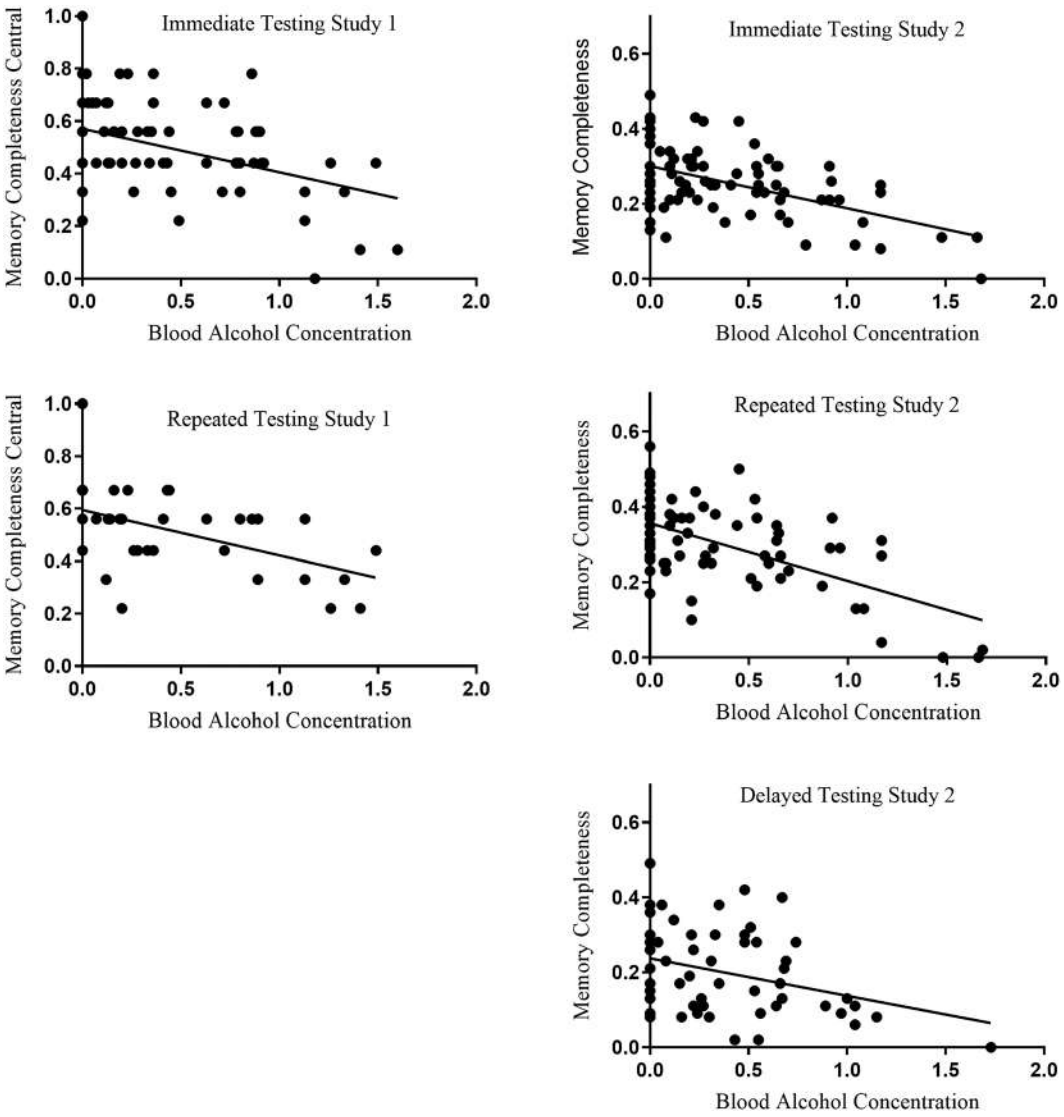


FIGURE 3 Memory completeness as a function of blood alcohol concentration for Study 1 and Study 2.

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effect on either the immediate, b = 0.02, Wald $\chi^2(1)$ = 0.34, p = .557, or repeated, b = −0.137, Wald $\chi^2(1)$ = 3.46, p = .063) test.

AMT predicts a differential BAC effect for central and peripheral details, but makes no predictions for time of testing. The current findings do not support AMT because BAC had a negative impact on completeness of both central and peripheral memory reports. Similarly, BAC did not affect accuracy for either central or peripheral details. Figure 3 displays the distributions of memory completeness as a function of BAC for immediate, repeated, and delayed-only testing for a comparison between Study 1 and Study 2.

6.5 | Misinformation acceptance.

6.5.1 | Immediate versus delayed-only testing

For acceptance of misinformation comparisons between the immediate and delayed-testing only group, we found a significant Time of Testing × BAC interaction, b = 1.85, β = 0.32, t = 2.81, p = .006. Simple slopes analyses revealed that higher BACs resulted in an increased tendency to adopt misinformation in the delayed-testing only condition, b = 1.88, β = 0.44, t = 3.60, p = .001, but not in the immediate testing condition, b = 0.02, β = 0.01, t = 0.05, p = .958, thereby partly supporting Hypothesis 3a, which states that intoxication increases the tendency to adopt misinformation. As in Study 1, (marginally) significant correlations were found between BAC and the tendency to adopt misinformation (r = .15, p = .056), between BAC and memory completeness (r = −.40, p < .001), and between memory completeness and the tendency to adopt misinformation (r = −.21, p = .008). Multiple regression similar to Study 1 returned a significant effect of memory completeness, b = -2.39, β = −0.18, t = −2.08, p = .039, but not BAC, b = 0.35, β = 0.08, t = 0.94, p = .348, on the tendency to adopt misinformation, which supports full mediation by memory completeness, in line with discrepancy detection theory (Hypothesis 3b). In other words, a reduction in memory completeness increased the tendency to adopt misinformation. Taken together, BAC undermined memory, and memory completeness mediated the tendency to adopt misinformation. Because memory was less complete on a delayed test, the misinformation effect was only significant on the delayed test. Table 5 shows how completeness, accuracy, and misinformation acceptance were affected by increasing levels of intoxication, in a similar dose-response way as in Study 1. Accordingly, memory completeness is expected to decrease about 10% at a BAC level of 0.09 and with almost 20% at a BAC of 0.21 as compared with intoxication that is still below the drink drive limit.

6.5.2 | Immediate versus repeated testing

When comparing misinformation acceptance on an immediate test with a repeated test, only the effect of session was significant, b = 0.37, Wald $\chi^2(1)$ = 5.36, p = .021, indicating that misinformation acceptance increased at repeated compared with immediate testing. This finding is the opposite of that of Study 1.

TABLE 5 Predicted outcome scores based on different BAC levels for different dependent variables (Study 2)

	BAC level in percent						
	0.03	0.06	0.09	0.12	0.15	0.18	0.21
Completeness total[a]	0.27	0.24	0.21	0.17	0.14	0.11	0.08
Completeness central details[a]	0.36	0.32	0.27	0.23	0.19	0.15	0.11
Completeness peripheral details[a]	0.19	0.17	0.15	0.12	0.10	0.08	0.06
Misinformation acceptance[b]							
Session 1[c]	1.60	1.61	1.61	1.62	1.62	1.63	1.63
Session 2[d]	2.56	3.12	3.69	4.25	4.81	5.38	5.94

Abbreviation: BAC, blood alcohol concentration.

[a]Based on BAC main effect, controlling for time of testing.

[b]Based on the BAC × Time of Testing interaction.

[c]Nonsignificant simple effect.

[d]Significant simple effect, increase of 0.03 units of alcohol per level.

Overall, intoxication reduced total memory completeness and accuracy on a repeated test, and only sober participants benefited from repeated testing. Regardless of intoxication level, all participants had a higher tendency to adopt misinformation on a repeated test.

7 | GENERAL DISCUSSION

In two field studies, we investigated whether immediate, repeated (Study 1), and delayed testing (Study 2) of (previously) intoxicated participants differentially affected the accuracy and completeness of memory reports (Aim 1), whether the effects of intoxication on memory depended on event salience (Aim 2), and whether intoxication increased susceptibility to misinformation acceptance (Aim 3). Table 1 displays the expected outcomes based on the theories that we tested and which predictions were supported by the data.

Our overarching aim was to shed more light on the question of when to obtain testimony from an intoxicated witness in order to minimize the risk of memory errors, whereas maximizing the reliability of testimony in terms of proneness to accept misinformation. Previous studies recommended sobering up, because delayed (repeated) sober questioning led to more complete memory reports and reduced suggestibility, compared with immediate recall (Hagsand et al., 2017; Van Oorsouw et al., 2015; Yuille & Tollestrup, 1990), but that immediate recall was beneficial over delayed-only recall (Hagsand et al., 2017; Hildebrand Karlén et al., 2017; Schreiber Compo et al., 2017). Although some differences were found for completeness and accuracy, overall, both studies demonstrated the undermining effect of intoxication in line with previous findings (e.g., Flowe et al., 2016; Van Oorsouw & Merckelbach, 2013; Van Oorsouw et al., 2015; Yuille & Tollestrup, 1990). Support was found for consolidation theory in a dose-dependent way; higher intoxication levels more strongly undermined memory than low levels (Hypothesis 1a, cf. Tables 3 and 5). A repeated test was beneficial in Study 2, but this effect was largely

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carried by sober participants, again supporting consolidation theory (Dudai, 2004) for intoxicated participants, and reminiscence for sober individuals (Hypothesis 1*b*; Lee et al., 2009). Immediate testing was clearly preferable over a delayed-only test, in support of decay theory (Hypothesis 1c; Barrouillet et al., 2004; Ebbinghaus, 1964; Kelley, 2014) and in line with previous findings (Hagsand et al., 2017; Hildebrand Karlén et al., 2017; Schreiber Compo et al., 2017).

Our second aim was to investigate whether the effects of alcohol on memory depend on event salience (i.e., AMT). Across both studies, we found only limited evidence in support of AMT (Hypothesis 2). Contrary to AMT predictions, memory for central details was negatively affected by intoxication in both studies, whereas the results for memory for peripheral details were inconsistent. Study 1 showed that only memory for central details was impaired by intoxication, independent of whether participants were questioned immediately or repeatedly. In Study 2, when comparing an immediate with a delayed-only test, memory for both central and peripheral details decreased when intoxicated. Both of these findings are contrary to AMT predictions. Yet, the comparison between immediate and repeated testing in Study 2 provided some evidence in support of AMT. In an immediate test, participants recalled central memory details somewhat better than peripheral details. Nevertheless, significant intoxication effects emerged for both types of details. Overall, the present data suggest that alcohol myopia is not a suitable model for explaining the processing of memories, although under the influence of alcohol. This is in line with some studies (Crossland et al., 2016; Flowe et al., 2016; Van Oorsouw & Merckelbach, 2012), but contrary to others suggesting that the more central cues are not affected by intoxication due to narrowing of attention (Schreiber Compo et al., 2011).

Our third aim was to investigate whether intoxicated individuals were more prone to accept misinformation (Hypothesis 3a) and whether the increased proneness would be mediated by memory performance, as suggested by discrepancy detection theory (Hypothesis 3b). As predicted, intoxication made individuals more prone to accept misinformation in both studies. Moreover, in line with previous findings (Van Oorsouw et al., 2015), memory completeness mediated the misinformation effect in two of the three comparisons in Studies 1 and 2, supporting discrepancy detection theory.

7.1 | Implications

Police investigators believe that it is best to have an intoxicated person sober up before questioning them about a pertinent event (Evans et al., 2009; Van Oorsouw et al., 2013). This idea was supported by studies that showed that sober (repeated) testing improved memory performance as opposed to intoxicated testing (Flowe et al., 2016; Van Oorsouw et al., 2015; Yuille & Tollestrup, 1990). However, repeated testing, rather than being sober, may have caused memory improvement, and the same might not be the case for delayed-testing only. This shortcoming was recently addressed in three studies (Hagsand et al., 2017; Hildebrand Karlén et al., 2017; Schreiber Compo et al., 2017). Most likely, due to lack of variation and low intoxication levels of 0.05% to 0.07% BAC, Hagsand et al. (2017) found no effects of intoxication on memory performance on immediate or delayed testing, but delayed testing undermined memory performance. Similarly, Schreiber Compo et al. (2017) with peak BACs of 0.08, did not find an intoxication effect at immediate recall, but did on a delayed, sober recall. Finally, Hildebrand Karlén et al. (2017) did find an effect of alcohol and time of testing in participants with highly varying levels of intoxication (0.00%–0.15% BAC), with the poorest performance on a delayed-only test. These findings support decay theory, which predicts that the passage of time, lack of rehearsal and interfere,nce of other information undermines intoxicated memories. The current Study 2 employed a similar design as Schreiber Compo et al. (2017) and Hildebrand Karlén et al. (2017), also testing a wide range of intoxication levels (up to 0.20% BAC). Besides replicating previous findings (alcohol intoxication undermined memory performance), delayed-only testing reduced memory completeness and increased the susceptibility to accept misinformation, relative to immediate testing. This suggests that the detrimental effect of an average of 5–7-day delay in the present studies (e.g., lack of rehearsal, decay, and interference) could not be compensated for by improved retrieval circumstances (e.g., focused attention, quiet environment, and being well rested) during sober testing after this delay. We argue that memory-undermining effects as predicted by consolidation and decay theory explain the detrimental effect of intoxication in a delayed test. Yet, despite the benefit of immediate testing, and in line with Hildebrand Karlén et al. (2017), the present findings also demonstrate the undermining effect of alcohol on memory completeness on such an immediate test, albeit smaller than in a delayed-only test. One explanation for this finding could be that alcohol may narrow attention in a temporal fashion, as suggested by Fleming et al. (2013). The finding that overall memory is better on an immediate test could be tentative evidence for attentional narrowing to the most recent events right before being interviewed, and not to past events when being interviewed on a delayed test. However, it is difficult to isolate temporal attention effects from decay effect, and clearly, this issue warrants further investigation.

As the dose-response patterns in Tables 3 and 5 show, in sober to mildly intoxicated participants, memory for the interaction was not affected strongly. This corresponds to findings from studies investigating alcohol effects that did not find an effect on memory at relatively low levels of intoxication (e.g., Hagsand et al., 2017; Schreiber Compo et al., 2017) and suggests that memory completeness and accuracy of someone with low BACs is not strongly affected when questioned immediately. However, it is important to note that Hagsand et al. (2016) and Schreiber Compo et al. (2017) did find memory-undermining effects of intoxication in delayed testing. Those results can be explained by decay effects. When intoxication levels rise, caution is warranted at immediate testing, in line with consolidation theory as well as at delayed testing where the combined effects of poor consolidation and decay come at the cost of memory completeness and accuracy.

What can be said about repeated testing? In contrast to earlier findings (Flowe et al., 2016; Van Oorsouw et al., 2015; Yuille & Tollestrup, 1990), the current two field studies only found a benefit

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of repeated testing for previously sober, but not previously intoxicated participants. This is in agreement with previous work that has shown that it is common for sober witnesses to recall reminiscent details at subsequent recall (e.g., Gilbert & Fisher, 2006). This suggests that, in line with the reported reminiscence effect (Hagsand et al., 2017), repeated testing can be beneficial for sober, but not intoxicated witnesses. In severely intoxicated participants, repeated testing showed the opposite effect, namely a reduction in peripheral memory accuracy (i.e., fabrication of new details or modifying details). For sober participants, repeated testing is advisable.

The findings on misinformation acceptance were inconsistent across the two studies. We expected misinformation acceptance to increase with rising intoxication levels, which we found in both studies. However, effects of time of testing were mixed. Misinformation acceptance was reduced on a repeated test in Study 1 and increased, regardless of intoxication level, in Study 2. We cannot readily explain this discrepancy, but speculate that memory could not improve much on the repeated test in Study 1 due to ceiling effects on memory completeness. C might explain why there was little room for adopting suggestive information in Study 1 compared with in Study 2. In an earlier study, misinformation acceptance was unaffected in a repeated test, whereas shifting answers under authoritative pressure were reduced (Van Oorsouw et al., 2015). This means that participants became less willing to change their initial answer when they were (falsely) told it was incorrect, on a repeated, sober test as compared with an immediate test. Given these inconclusive findings, it is important that future studies further investigate how intoxication affects misinformation acceptance. Existing studies make no specific predictions about the acceptance of misinformation and time of testing. Rather, the discrepancy detection principle predicts proneness to accept misinformation to depend on memory completeness. That is, poor memory elicits difficulties in detecting differences between one's memory and suggested information, thereby making participants more vulnerable to yield to suggestive cues (Schooler & Loftus, 1986; Van Oorsouw et al., 2015). We did find that memory completeness mediated the relation between intoxication and the tendency to adopt misinformation in both studies. In delayed-only testing as opposed to immediate testing, intoxication increased misinformation acceptance. This confirms the idea that poor memory due to decay and delay makes it more difficult to detect discrepancies and increases suggestibility.

All in all, the present findings suggest that for intoxicated witnesses, an immediate interview seems preferable, compared with a first interview after a detoxification period. It depends on the level of intoxication what recommendations can be made regarding repeated testing.

One might object that intoxicated interviewing poses ethical risks, including impaired ability to understand legal procedures and providing informed consent. Yet, these risks are minimal compared with suspect procedures, where the risk of self-incrimination, waiving rights (e.g., to remain silent), or making a false confession could outweigh the access to accurate memory reports, deeming an intoxicated interview ethically irresponsible. To be sure, it is important that no misinformation is presented in such an interview and that the interview takes place in a structured way. As suggested by Crossland et al. (2016), the cognitive interview (CI; Geiselman, Fisher, MacKinnon, & Holland, 1985) may prove useful to support intoxicated witnesses' retrieval. The CI uses multiple retrieval techniques that optimizes the activation of different cognitive pathways to each memory trace and includes contextual information and retrieval support to aid the retrieval process. It leaves little room for the presentation of misinformation, which is one of the risks of questioning intoxicated witnesses. In addition, intoxication has a larger effect on free as compared with cued recall (see also Van Oorsouw et al., 2015). Using a more structured recall format using targeted probing as in CI could positively affect recall, especially at low to moderate levels of intoxication when some retrieval cues are stored.

7.2 | Limitations

Turning to the limitations of the current studies, delay between test sessions was confounded with being sober (again) although tested. Specifically, participants who were intoxicated during Session 1 could only be tested in a sober condition with a delay and participants who were sober during Session 1 were also sober during Session 2. Hence, we cannot disentangle the negative effects of delay and the (positive) effects of sobering up. However, Schreiber Compo et al. (2017) used a state-dependent memory paradigm and found a similar pattern of findings, thereby lending support to the idea that an immediate test is preferable. Future studies may choose for a more complex, experimental design in that intoxication in both sessions is varied as done by Schreiber Compo et al. (2017). Such a design is difficult to employ in a field study, but may be feasible in a controlled lab setting.

Potential ceiling effects due to insufficient questions in Study 1 pose another limitation of the present work. Due to the ceiling effects, some findings could not be interpreted and remain speculative (e.g., not finding an increase in misinformation acceptance in Session 2).

Furthermore, one could argue that the criteria for defining central and peripheral details in the present study were arbitrary and caused these inconsistent findings. Although we followed previous work that coded target details as central, and surroundings as peripheral, we could not find information on salience of conversation details and based our definition on common sense. One could claim that conversation details should be coded as peripheral at all times. Another limitation concerns the variation in delay between the first and second test session. Delay varied a lot between participants with an average of 5 to 7 days in Studies 1 and 2, respectively. With shorter delays, we may not have found such detrimental effects of delayed-testing only. Future studies should invite participants to the lab for the second test to overcome this problem and create a controlled variation in delay and include random allocation to intoxication level to prevent self-selection bias. On the other hand, ethical constraints often challenge the administration of high doses of alcohol in a laboratory setting. The current nonexperimental design, despite its limitations, overcomes such ethical constraints and creates an ecologically valid setting.

Finally, as can be seen in Figures 1 and 2, alcohol intoxication was right-skewed with a predominance of sober participants and a range

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of intoxication levels, showing a small number of extremes at the right end of the distribution. Although for most of the analyses, the distribution of residuals was acceptably symmetric (Stevens, 1992); analyses for Study 2 did reveal some heteroskedasticity related to the skewed distribution of intoxication. Future field studies may want to aim for a better distribution over different intoxication levels.

8 | CONCLUSION

From the present studies, we can conclude that alcohol impairs eyewitness memory and introduces a risk of adopting misinformation. This risk increases with rising intoxication levels and even more so with the passage of time. The present findings suggest that in a witness situation, it is advisable to have witnesses testify immediately and not when they have sobered up. At relatively low intoxication levels, a repeated test could lead to increased recall performance due to reminiscence effects. In any case, investigators should realize that when intoxication levels are high, testimony becomes less reliable.

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How to cite this article: van Oorsouw K, Broers NJ, Sauerland M. Alcohol intoxication impairs eyewitness memory and increases suggestibility: Two field studies. *Appl Cognit Psychol*. 2019;33:439–455. https://doi.org/10.1002/acp.3561

APPENDIX A

QUESTIONS USED IN STUDY 1

Question type	Question asked
Open	1. Describe the conversation you had as completely as possible.
Open	2. Describe the person who you spoke with. (Think about appearance, hair, build, clothes and distinguishing features.)
Misinformation	3. Did the person come from Den Bosch or Weert
Misinformation	4. Did the person have a nose piercing on the left or right side?
Cued	5. How long do you think did your conversation lasted?
Misinformation	6. Did the person have a glass of white or red wine in her hand?
Cued	7. What did the person fetch out of her handbag first?
Cued	8. Did the person wear glasses?
Misinformation	9. Which color did the handbag of the person have? Black or blue?
Misinformation	10. Why was an ambulance mentioned during the telephone conversation? Because someone was run into or because someone fell off their bike?

APPENDIX B

QUESTIONS USED IN STUDY 2

Question type	Question asked
Open	1. Describe the conversation you had as completely as possible.
Open	2. Describe what the person wore and if she carried anything with her.
Cued	3. Did the person come from Sittard?
Cued	4. What kind of bag did the person carry?
Misinformation	5. Was the person called Linda?
Misinformation	6. Did the person have a glass of beer or wine in her hand?
Cued	7. With whom did the person come to Maastricht?
Misinformation	8. Was the scarf of this person black or green?
Misinformation	9. Was it the birthday of one of her friends?
Misinformation	10. What did the person say how often she travelled to Maastricht?
Cued	11. Did the person carry anything over her arm? If so, what?
Cued	12. What did the person fetch out of her bag?
Cued	13. What was the reason that the person had lost her friends?
Misinformation	14. When during the conversation did the person drop her phone?
Misinformation	15. Did the person study law or medical science?
Misinformation	16. Did the person ask whether this street was the Platielstraat?
Cued	17. Did the person wear anything in her hair? If so, what?
Misinformation	18. Did the friends of the person say they were (in the bar) Twee Heeren or the FM?
Cued	19. How was the conversation terminated?

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