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Fast track report

Lasting effects of alcohol: Subliminal alcohol cues, impairment expectancies, and math performance

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Abstract

Many people believe that drinking alcohol reduces cognitive performance, and prior research has shown such expectancy-related impairment even when people merely thought that the (non-alcoholic) drink they consumed contained alcohol. This study tested whether subliminal priming with alcohol-related cues would similarly result in expectancy-consistent cognitive performance decrements. Additionally, the moderating role of alcohol use was examined. After assessing participants' baseline math performance, participants were primed with alcohol-related or neutral words and then completed a post-treatment math task. Whereas impairment expectancies had no influence on math performance in control participants, expectancies predicted math performance for participants primed with alcohol-related words. As hypothesized, expectancy-consistent impairment in performance was only observed among high alcohol users. The current findings suggest that, in the presence of alcohol-related cues in the environment, some people may perform less on cognitive tasks even in the absence of actual or assumed alcohol consumption and without being aware of it. Copyright © 2011 John Wiley & Sons, Ltd.

It is generally accepted that alcohol consumption lowers inhibitions and impairs cognitive and motor performance. Contrary to lay beliefs that these effects are solely due to the pharmacology of alcohol, people's expectancies about the consequences of alcohol consumption can be a contributory factor as well. Considerable research has shown that people behave in line with their expectations regarding alcohol use whenever they believe that they have consumed alcohol, regardless of whether they actually consumed an alcoholic drink or a placebo (e.g., Hull & Bond, 1986; Marlatt & Rohsenow, 1980). In the present study, we examined whether subliminal exposure to alcohol-related primes (e.g., words associated with alcohol) would similarly engender expectancy-consistent behavior related to cognitive performance. Confirmation of this hypothesis would mean that, even in the absence of actual or assumed alcohol consumption and without being aware of it, some people are likely to perform less well on cognitive tasks when their environment confronts them with alcohol-related cues (e.g., a businessman who attends a meeting in a restaurant and believes that alcohol leads to cognitive impairment).

The effects of alcohol-related impairment expectancies on cognitive performance have been demonstrated in balanced placebo design studies that pit the alcohol expectancy effects against the pharmacological consequences of alcohol. For instance, in one study, male social drinkers assigned to the experimental conditions consumed either an alcoholic or a non-alcoholic drink believing that it contained alcohol (Fillmore, Carscadden, & Vogel-Sprott, 1998). In the control condition, participants were not given any drink. Cognitive performance was assessed with a Rapid Information Processing task, and task-specific expectancies regarding the impact of alcohol were assessed after a practice session with the task. To control for individual differences in performance, participants performed the task once before and once after the experimental manipulation. Results showed that impairment expectancies decreased cognitive performance in both experimental conditions but not in the control condition. Thus, alcohol-related impairment expectancies predicted cognitive performance even when people merely believed that they had consumed alcohol.

More recent research suggests that actual or assumed alcohol consumption is not even required for explicit alcohol expectancies to influence cognition and behavior (Bartholow & Heinz, 2006; Friedman, McCarthy, Bartholow, & Hicks, 2007; Friedman, McCarthy, Förster, & Denzler, 2005). For instance, Friedman et al. (2005) briefly exposed male participants to alcohol-related words (e.g., beer) or non-alcohol words (e.g., water) before rating the attractiveness of photographed young women. Results showed that men with stronger expectancies that alcohol enhances sexual arousal rated the women as more attractive following exposure to alcohol-related words relative to non-alcohol words. Similarly, alcohol-related cue exposure has been shown to induce expectancy-consistent behavior regarding tension reduction and aggression (Bartholow & Heinz, 2006; Friedman, et al., 2007). Although these studies demonstrate that even subtle exposure to alcohol-related cues

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promotes expectancy-consistent behavior, they limited themselves to investigating social behaviors. The present study therefore aimed at opening up this area of research to a wider range of behaviors by investigating whether alcohol-related cue exposure results in expectancy-consistent cognitive performance, hence, a non-social behavior. Specifically, we tested if explicit alcohol-impairment expectancies related to math ability would predict performance on a math task when subliminally primed with alcohol-related (vs. non-alcohol) words.

To date, no research has investigated the interactive effects between alcohol priming and alcohol-related impairment expectancies on non-social behaviors. It thus remains to be empirically demonstrated whether subliminal exposure to alcohol-related cues even influences seemingly higher level functions such as cognitive performance. Demonstrating effects on cognitive performance following subliminal exposure to alcohol-related cues would add importantly to previous work by directly assessing actual behavior instead of measuring the activation of aggressive thoughts (Bartholow & Heinz, 2006), or employing self-report measures of tension reduction or target attractiveness and hostility (Bartholow & Heinz, 2006; Friedman, et al., 2007; Friedman, et al., 2005). In addition, effects of alcohol-related impairment expectancies on cognitive performance tend to go unnoticed and thus could have far more detrimental consequences. In contrast, changes in overt social behavior (e.g., behaving aggressively) are more likely to be noticed by others and, hence, might be easier to correct for. Together, investigating how alcohol-related primes interact with people's expectancies to influence cognitive performance should provide novel insight into the subtle and potentially far-reaching impact of alcohol expectancies on behavior.

The findings that exposure to alcohol cues induces expectancy-consistent behavior are in line with a large body of social cognition research (for reviews, see Bargh & Chartrand, 1999; Dijksterhuis, Chartrand, & Aarts, 2007), showing that conscious or unconscious activation of mental constructs (e.g., traits, stereotypes) implicitly co-activates behavioral scripts related to these constructs which subsequently influence people's thoughts, feelings, and behaviors. For instance, activation of the elderly stereotype induces people to walk more slowly (Bargh, Chen, & Burrows, 1996), and activating the college professor stereotype makes people behave smarter (Dijksterhuis & Van Knippenberg, 1998). Moreover, it has been argued that people who more easily retrieve such implicit memory associations (this refers to greater cognitive accessibility or associative strength, not extremity of the associations) should be more sensitive to behave in line with the activated construct (Dijksterhuis, Aarts, Bargh, & Van Knippenberg, 2000). Consistent with this, research showed that people primed with the elderly stereotype performed less on a memory task only when they strongly associated elderly with forgetfulness (Dijksterhuis, et al., 2000). People with strong associations between elderly and forgetfulness (i.e., high cognitive accessibility) were those who reported to have had a great deal of contact with elderly people.

In a similar vein, it has been proposed that greater experience with alcohol increases the associative strength between alcohol and alcohol-expected outcomes (Goldman, 1999). This suggests that people who consume more (vs. less) alcohol should be more likely to show expectancy-consistent behavior in the presence of alcohol-related cues because for them implicit memory associations between alcohol and alcohol outcomes are more easily activated upon confrontation with alcohol cues. In contrast, alcohol cues are less likely to activate such implicit alcohol-related associations in people who drink less, which in turn should prevent alcohol expectancies to influence behavior. Put differently, explicit alcohol-impairment expectancies should predict cognitive performance following subliminal alcohol-cue exposure for high alcohol users but not (or to a lesser extent) for low alcohol users. Evidence in support of this hypothesis is ambiguous. Previous research on alcohol priming and expectancies either did not report testing the interaction between cue exposure, outcome expectancies, and alcohol use (Bartholow & Heinz, 2006; Friedman, et al., 2005)[1] or found no support (Friedman, et al., 2007). However, recent research demonstrated that, following marijuana-cue exposure, marijuana-impairment expectancies predicted cognitive performance only for people who had smoked marijuana but not for those who abstained from marijuana in the past year (Hicks, Pedersen, McCarthy, & Friedman, 2009). Because of the latter findings and earlier social cognition research (Dijksterhuis, et al., 2000), we further addressed this issue by investigating whether exposure to alcohol-related cues interacts with both explicit alcohol-impairment expectancies and alcohol use to influence cognitive performance.

STUDY OVERVIEW

In the present study, participants were subliminally exposed to alcohol-related or control cues after completing a baseline math task. After the priming task, participants completed a post-treatment math task. Participants' explicit expectancy regarding the impact of alcohol on math ability and their alcohol use were assessed afterwards. We predicted an interaction between prime condition, impairment expectancy, and alcohol use. Specifically, we hypothesized that explicit alcohol-impairment expectancies would only predict math performance following subliminal alcohol-cue exposure for high alcohol users but not (or to a lesser extent) for low alcohol users. Following exposure to control cues, no effect of impairment expectancies on math performance was expected.

METHODS

Participants

In total, 74 university students (36 men, 38 women; $M_{age} = 21.29$ years, $SD_{age} = 3.14$ years) were randomly assigned to the control or alcohol prime condition and received €2 or

[1]Bartholow and Heinz (2006) did test a model in which alcohol use, prime condition, and their interaction were entered to predict hostility ratings. They found a main effect of alcohol use but no interaction with prime condition. Importantly, the authors did not report a test of the three-way interaction including expectancy ratings.

course credit for participation. Two participants were identified as outliers in box plots and excluded from further analyses: Both scored outside the normal range on the alcohol use measure (> 4 *SD*s from the mean).

Materials and Measures

Baseline Math Performance

Participants completed a math task in which they had to indicate as quickly as possible, by pressing a key, whether the equation presented on the screen was correct or not. They judged 30 moderately complex equations (adopted from Van Dillen & Koole, 2007), such as "19 + (3*7) = 40." All equations combined a summation or subtraction with a product or a division, and the response per equation for each participant was recorded ($M_{\text{correct responses}} = 27.54$, $SD = 1.99$). The trials were randomly presented and were preceded by five practice trials.

Priming Task

A lexical decision task was used to subliminally prime participants with alcohol versus control words (cf. Friedman, et al., 2005). Participants had to indicate as quickly and accurately as possible, by pressing a key, whether a word presented on the screen was an existing word or a non-word. Ten practice trials were presented to familiarize participants with this task. The actual lexical decision task contained 110 trials, and every trial began with a fixation point (*) for 1000 milliseconds. In each trial, participants were primed subliminally with either a randomly selected alcohol-related word (alcohol prime condition) or control word (control prime condition). We used 11 alcohol (e.g., beer, wine, whisky, vodka, cocktail, rum) and 11 control prime words (e.g., water, juice, tea, lemonade, smoothie, milk), and each word was presented 10 times. The prime word was preceded by a pre-mask (unreadable letter string) that remained for 400 milliseconds. Then the prime was presented for 34 milliseconds, followed by a post-mask (unreadable letter string) for 400 milliseconds. Thus, proper pre-masking and post-masking rendered the very briefly presented primes impossible to detect consciously. Finally, participants were presented randomly with a word or non-word that remained on the screen until a response was made. All materials were presented in white capital letters (Courier New, 18 pt bold style) on a black background in the center of the screen (i.e., primes were foveally presented) of a 17-inch monitor (60 Hz; 640 × 480 resolution).

Post-treatment Math Performance

Participants completed a similar math task that was used to assess baseline performance and judged 30 different moderately complex equations ($M_{\text{correct responses}} = 26.68$, $SD = 2.22$).

Explicit Impairment Expectancy

Participants indicated on a nine-point scale how they expected "two glasses of alcohol drunk in 1 hour (e.g., two beers or wine)" would affect their ability to solve math equations quickly and accurately (1 = *much more difficult*, 5 = *no effect*, 9 = *much more easier*). This question was modeled after questions used in previous research (Fillmore, et al., 1998; Fillmore & Vogel-Sprott, 1995). The question was reverse scored such that higher scores reflect a greater degree of expected impairment ($M = 6.83$, $SD = 1.01$; mean range of 6.00 to 9.00).

Alcohol Use

Participants first indicated on how many of the four weekdays (Monday through Thursday), on average, they drink alcohol. They then reported the average number of glasses they drink on a weekday. Participants were then asked to report on how many of the three weekend days (Friday through Sunday), on average, they drink alcohol and to report the average number of glasses they drink on a weekend day. Weekday and weekend day alcohol consumption were determined by multiplying number of drinking weekdays and weekend days with number of glasses on week and weekend days, respectively. Alcohol use was then calculated by summing weekday and weekend day alcohol consumption ($M = 9.06$, $SD = 9.82$).

Procedure

Upon arrival, participants were seated in individual cubicles with a computer. The research was described as consisting of several separate unrelated parts. Participants first completed the baseline math task that was presented as a project in which equations were piloted for future use. They were told that this task was divided in two parts. After the first part (i.e., baseline assessment), participants completed the lexical decision task, in which they were either primed with alcohol-related or control words. They then completed the second part of the math task (i.e., post-treatment assessment). After completing the questions measuring the expected degree of impairment and alcohol use, participants were extensively debriefed to assess their awareness of the true nature of the study and whether they had seen the presented primes. Participants were asked to describe what they believed the tasks assessed and to report any remarks they had about the tasks, whether they believed the different parts to be related and whether this affected them and, if so, to describe how. After asking participants if they had noticed anything unusual about the letter strings in the lexical decision task, they were informed that they had been presented with prime words. Participants were then asked if they had noticed the primes and, if so, to write down what words or what kind of words they had seen. No participants reported seeing the word primes or guessed the true nature of the study.

RESULTS

Conditions were compared on baseline math performance, age, gender, explicit impairment expectancy, and alcohol use. No analysis was significant, all Fs < 1, ps = .91 to .34, all η_p^2s < .01, suggesting successful randomization and that participants' explicit impairment expectancy was not influenced by the priming task. Gender did not affect the results reported below.

Post-treatment math performance (i.e., the total number of correct responses) was analyzed in the general linear model (GLM) as a function of prime condition, impairment expectancy, and alcohol use and their interactions. To correct for individual differences in math performance, we included baseline performance in the model. Continuous predictor variables were standardized, and the condition variable was dummy coded.

The analysis revealed a significant effect of baseline performance, $F(1, 63) = 16.91$, $p < .001$, $\eta^2_p = .21$, indicating that greater performance at baseline was associated with greater post-treatment math performance. This effect was qualified by a significant Prime × Alcohol Use × Expectancy interaction, $F(1, 63) = 7.90$, $p = .007$, $\eta^2_p = .11$. To test our hypothesis, the effects of alcohol use and expectancy on performance were tested in the control and alcohol prime conditions separately.

In the control prime condition, baseline performance was positively related to post-treatment math performance, $F(1, 34) = 10.68$, $p = .002$, $\eta^2_p = .24$. The effects of alcohol use, $F < 1$, impairment expectancy, $F(1, 34) = 1.10$, $p = .30$, $\eta^2_p = .03$, and their interaction, $F(1, 34) = 1.31$, $p = .26$, $\eta^2_p = .04$, were not significant.

In the alcohol prime condition, baseline performance was positively related to post-treatment math performance, $F(1, 28) = 6.27$, $p = .018$, $\eta^2_p = .18$. The main effects of alcohol use and impairment expectancy were not significant, both Fs < 1. However, the analysis also revealed a significant Alcohol Use × Expectancy interaction, $F(1, 28) = 11.07$, $p = .002$, $\eta^2_p = .28$. Subsequent analysis showed that for low alcohol users (one *SD* below the mean of alcohol use), expectancy did not predict post-treatment performance, $F(1, 28) = 2.13$, $p = .16$, $\eta^2_p = .07$. In contrast, for high alcohol users (one *SD* above the mean of alcohol use), impairment expectancy proved to be a significant predictor of post-treatment math performance, $F(1, 28) = 6.24$, $p = .019$, $\eta^2_p = .18$, such that a greater degree of expected impairment was associated with decreased performance on the post-treatment math task.

In line with our predictions, the above analyses demonstrate that explicit alcohol-impairment expectancies only predict math performance following subliminal alcohol-cue exposure for high alcohol users but not for low alcohol users. But does math performance of high alcohol users who believe that alcohol leads to impairment actually deteriorate when they are exposed to alcohol cues? We tested this in an additional GLM analysis on math performance with math task (baseline vs. post-treatment) as within-subjects factor, prime condition (control vs. alcohol) as a between-subjects factor, and impairment expectancy and alcohol use as continuous predictors.

This analysis revealed a main effect of math task, $F(1, 64) = 10.67$, $p = .002$, $\eta^2_p = .14$. Overall, the performance of participants was better on the baseline math task ($M = 27.62$, $SE = 0.23$) than on the post-treatment math task ($M = 26.82$, $SE = 0.24$). This effect was qualified, however, by a four-way interaction of math task, prime condition, alcohol use, and impairment expectancy, $F(1, 64) = 3.97$, $p = .05$, $\eta^2_p = .06$. The analysis in the control prime condition only revealed a main effect of math task with control participants performing better on the baseline math task ($M = 27.46$, $SE = 0.36$) than on the post-treatment math task ($M = 26.74$, $SE = 0.34$), $F(1, 35) = 4.31$, $p = .045$, $\eta^2_p = .11$. In the alcohol prime condition, the analysis revealed a similar main effect of math task, $F(1, 29) = 6.63$, $p = .015$, $\eta^2_p = .19$ ($M_{baseline} = 27.79$, $SE = 0.27$; $M_{post\text{-}treatment} = 26.92$, $SE = 0.35$), which was qualified by a significant Math Task × Alcohol Use × Expectancy interaction, $F(1, 29) = 9.92$, $p = .004$, $\eta^2_p = .26$.

Among participants primed with alcohol cues, who strongly believed that alcohol would impair their performance (1 *SD* above the mean of the expectancy measure), subsequent analyses revealed a significant Math Task × Alcohol Use interaction, $F(1, 29) = 7.24$, $p = .012$, $\eta^2_p = .20$, whereas the main effect of math task was not significant, $F(1, 29) = 2.36$, $p = .14$, $\eta^2_p = .08$. As can be seen in Figure 1, for low alcohol users, there was no difference between baseline and post-treatment math performance, $F < 1$. In contrast, the performance of high alcohol users decreased from baseline to post-treatment, $F(1, 29) = 8.12$, $p = .008$, $\eta^2_p = .22$. Among participants in the alcohol prime condition who less strongly believed that alcohol would impair their performance (1 *SD* below the mean of the expectancy measure), the analyses only revealed a main effect of math task, $F(1, 29) = 5.16$, $p = .031$, $\eta^2_p = .15$ ($M_{baseline} = 28.46$, $SE = 0.44$; $M_{post\text{-}treatment} = 27.43$, $SE = 0.47$), whereas the Math Task × Alcohol Use interaction was not significant, $F(1, 29) = 1.31$, $p = .26$, $\eta^2_p = .04$.

DISCUSSION

Results of the present study show that following mere exposure to alcohol-related cues, alcohol-impairment expectancies influence performance on a cognitive task. Importantly, the impact of alcohol-impairment expectancies on performance was moderated by the level of people's alcohol use. Following subliminal priming with alcohol-related words, expectancies predicted post-treatment math performance for high alcohol users but not for those who use less alcohol. Moreover, math performance of high alcohol users with strong impairment expectancies deteriorated when exposed to alcohol-related cues. Unexpectedly, their low-alcohol consuming counterparts did

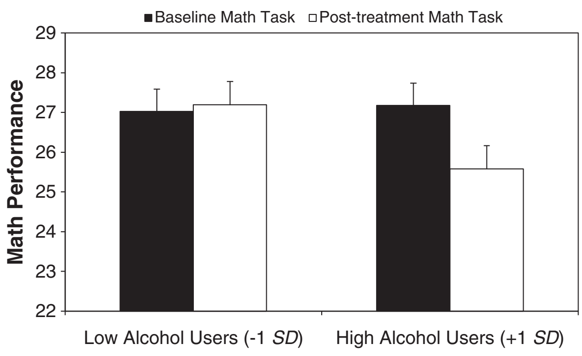

Figure 1. Mean math performance (i.e., total number of correct responses) of participants in the alcohol prime condition with strong impairment expectancies (1 *SD* above the mean of the expectancy measure) as a function of math task and alcohol use. Error bars represent the standard error

not show any performance decrement. Because overall, the performance of participants was better on the baseline math task than on the post-treatment math task, we would have expected some decrease in math performance in this condition as well. Impairment expectancies had no influence on math performance in control participants who were primed with neutral words. Together, the present findings replicate and extend previous research using a balanced placebo design (Fillmore, et al., 1998) by showing that alcohol-impairment expectancies predict cognitive performance even in the absence of actual or assumed alcohol consumption.

Our results are also consistent with recent studies demonstrating how alcohol-related primes interact with explicit alcohol expectancies to influence attractiveness ratings, tension reduction, and aggression (Bartholow & Heinz, 2006; Friedman, et al., 2007; Friedman, et al., 2005). However, the current study adds importantly to this work by showing that alcohol-related cues and impairment expectancies even influence higher level functions such as cognitive performance, hence, a non-social behavior. In addition, the present findings suggest that the effects may be limited to people who regularly consume alcohol. This latter result nicely fits with earlier social cognition research (e.g., Dijksterhuis, et al., 2000) and parallels recent findings in the marijuana literature (Hicks, et al., 2009).

Whereas our research did not directly examine the mechanism underlying the observed effects, we reasoned that the accessibility of implicit memory associations plays an important role in the emergence of expectancy-consistent behavior (cf. Dijksterhuis, et al., 2000; Friedman, et al., 2005; Goldman, 1999). Applied to the current results, this means that impairment expectancies only predict performance for high alcohol users because for them implicit memory associations between alcohol and alcohol outcomes are more easily activated upon confrontation with alcohol-related cues. This implies that alcohol cues fail to activate such implicit alcohol-related associations in people who drink less. Alternatively, activation of alcohol-related memory associations only affects cognitive performance when expected impairment is based on actual experience. Regular social drinkers may have personally experienced cognitive impairment during alcohol consumption more frequently. This may turn alcohol cues into conditioned stimuli, subsequently inducing expectancy-consistent behavior (Friedman, et al., 2005). An important avenue for future research would be to investigate these potential mechanisms by which alcohol cues, impairment expectancies, and alcohol use influence cognitive performance.

Future studies may also benefit from including a more diverse sample because this initial investigation only included a relatively small sample of university students. For instance, it seems important to investigate whether alcohol priming similarly influences performance of more problematic drinkers compared with regular social drinkers. Related to this point, follow-up research should include a wider range of measures, such as the Alcohol Use Disorder Identification Test (Saunders, Aasland, Babor, De la Fuente, & Grant, 1993), to obtain more detailed information about the drinking history of participants.

In conclusion, whereas most people accept that alcohol consumption can impair their cognitive performance, the present study shows that people's expectancies about the impact of alcohol can influence their performance even in the absence of actual alcohol consumption. To the extent that alcohol-related cues are present in the environment, some people may perform less on cognitive tasks without being aware of it. The observed expectancy-consistent behavior among regular drinkers in the present study seems to be a lasting, perhaps unexpected, effect of alcohol.

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