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# Implicit and Explicit Alcohol Cognitions: The Moderating Effect of Executive Functions

**Andrea M. Lavigne[1], Mark D. Wood[1,†], Tim Janssen[2,*], and Reinout W. Wiers[3]**

[1]Department of Psychology, The University of Rhode Island, Kingston, RI 02881, USA, [2]Center for Alcohol and Addiction Studies, Brown University, Box G-S121-4, Providence, RI 02912, USA, and [3]Addiction Development and Psychopathology (ADAPT) Lab, Department of Psychology, University of Amsterdam, Amsterdam, 1018 XA, the Netherlands

*Corresponding author: Center for Alcohol and Addiction Studies, Brown University, Box G-S121-4, Providence, RI 02912, USA. E-mail: tim_janssen@brown.edu

[†]Deceased in April 2015.

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## Abstract

**Aims:** Research informed by dual-process models of addictions has clearly demonstrated an association between implicit and explicit alcohol-related cognitions and alcohol consumption. However, the literature is limited with respect to examination of the cognitive abilities that may moderate these associations across populations. This study examined relations among alcohol associations, inhibition and alcohol consumption in a sample of college students. It was hypothesized that the executive ability of response inhibition would moderate relations between alcohol-related cognitions and alcohol consumption, such that individuals with weaker response inhibition would demonstrate stronger relations between implicit cognitions and use, while individuals with stronger response inhibition would demonstrate more robust relations between explicit cognitions and use.

**Methods:** Research participants ($N = 205$, age 19.0 years (standard deviation = 1.1)) mostly female ($n = 150$, 73.2%) completed two implicit association tasks measuring alcohol-related positive/arousal and relaxation associations. In addition, participants completed questionnaires regarding alcohol expectancies, alcohol consumption and problems, and various measures of inhibition. We tested study hypotheses using structural equation modeling and probed significant interactions using simple slope analyses.

**Results:** We found support for a moderating effect of response inhibition on relations between implicit relaxation associations and alcohol consumption. We did not find a moderating effect of working memory capacity on relations between alcohol-related associations and use.

**Conclusions:** Findings from this study further our understanding of differential cognitive and inhibition factors that contribute to underage alcohol consumption with implications for preventive interventions to reduce alcohol misuse and consequences.

**Short summary:** We investigated whether the effect of implicit and explicit alcohol associations on alcohol consumption was moderated by response inhibition and working memory among college students. Response inhibition moderated the effect of implicit relaxation associations on consumption. We did not obtain support for moderation by working memory, or of explicit associations.

## INTRODUCTION

Heavy drinking and alcohol-related negative consequences continue to be a significant public health issue among college students in the USA. Given the prevalence of alcohol misuse, much attention has been given to the cognitive processes involved. By studying these cognitive processes, alcohol researchers are able to elucidate the implicit associations and explicit cognitions individuals hold in memory and investigate their unique relations with measures of alcohol consumption, as reviewed next.

Implicit associations are relatively automatic associations formed over time that are 'triggered in the impulsive system from the activation of associative clusters in long-term memory' when individuals encounter stimuli, such as passing a bar (Hofmann *et al.*, 2008; p.115). Research has consistently demonstrated the utility of assessing implicit associations in the study of alcohol consumption (Stacy *et al.*, 1996; Palfai and Wood, 2001; Wiers *et al.*, 2002; Houben and Wiers, 2006; Thush and Wiers, 2007; Reich *et al.*, 2010). To date, positive and arousing implicit associations (e.g. associated with feeling excited) appear to be most strongly associated with alcohol consumption (Leigh and Stacy, 1998; Wiers *et al.*, 2002; Houben and Wiers, 2006, 2009). Furthermore, it has been demonstrated that social contexts, such as the background of a bar in alcohol pictures (Monk et al., in press) and the presence of friends of the opposite gender (Groefsema *et al.*, 2016) can enhance the effects of implicit associations to alcohol consumption. This further emphasizes that it is important to investigate moderators in the relation between implicit associations and alcohol consumption. Previous studies have demonstrated incremental validity of implicit cognitions showing that implicit association tests predicted unique alcohol consumption after explicit cognitions had been controlled for (Wiers *et al.*, 2002; Ostafin and Palfai, 2006; Thush *et al.*, 2007). However, other reasons for drinking also exist that may create implicit associations between stress/relaxation and alcohol consumption (e.g. alcohol is associated with coping with negative affect, offering relaxation), which is another known predictor of alcohol outcomes, particularly problem drinking (Littlefield *et al.*, 2010). Negative affect has been related to alcohol consumption via implicit cognitions (Ostafin and Brooks, 2011).

Explicit alcohol associations are 'anticipated effects of drinking alcohol' (Wiers and Stacy, 2010, p.13). Alcohol associations, such as those about the tension reducing effects of alcohol, have consistently been found to be associated with quantity and frequency of use and problems (Brown *et al.*, 1987; Fromme *et al.*, 1993). Collectively, findings provide support for the utility of assessing both implicit associations and expectancies given observed cross-sectional and prospective relations with alcohol and other drug outcomes (see also Wiers and Stacy, 2010).

Implicit cognitions are believed to influence behavior alongside explicit cognitions through dual-process theories of addiction (Stacy and Wiers, 2010). Such theories emphasize that alcohol stimuli may trigger impulsive appetitive processes on the one hand and reflective processes on the other. Thus, depending on the strength of impulsive processes and the relative weaknesses of reflective processes like response inhibition, individuals may be prone to use alcohol relatively automatically (Wiers *et al.*, 2007). Findings from research using a high-risk sample of alternative high school students revealed a moderating effect of response inhibition skills on alcohol approach tendencies both cross-sectionally (Peeters *et al.*, 2012) and longitudinally (Peeters *et al.*, 2013). Research on the moderating effect of response inhibition on implicit alcohol associations in college students is limited to a single study that took place in the Netherlands (Houben and Wiers, 2009). The results were consistent with a dual-process approach as individuals with higher response inhibition did not demonstrate significant relations between positive and arousal implicit associations and alcohol consumption, while individuals with lower response inhibition did.

Similar to response inhibition, working memory (WM) capacity has been suggested to determine the strength of reflective processes. Mediated by the dorsolateral prefrontal cortex, WM capacity 'hold information in an activated state for a short period of time … in order to make it available for further processing, manipulation and updating by higher cognitive processes' (Piechatzek *et al.*, 2009, p.651). Support for a moderating effect of WM capacity on relations between implicit alcohol associations and use have been found in American (Grenard *et al.*, 2008) and Dutch (Thush *et al.*, 2008) adolescent populations, such that individuals with weaker WM capacity showed stronger relations between implicit alcohol associations and use.

These and prior findings provide promising initial support for dual-process cognitive models of alcohol consumption, and the role of both WM capacity and response inhibition. We seek to extend previous work to determine whether findings in this area generalize to a sample of American college students, a population known to be at risk for alcohol-related problems. We also assess multiple measures of executive functioning to allow for greater delineation of inhibition functions. We predict that greater arousal and relaxation associations with alcohol will be more strongly related to alcohol consumption when response inhibition and/or WM capacity is low. In addition, this study is the first to our knowledge to examine relations between response inhibition and explicit associations. Our hypotheses reflect earlier findings demonstrating moderation of arousal/relaxation associations, implicit and explicit, by WM capacity. We additionally examine whether this moderation holds for a different moderator, response inhibition.

*Hypothesis 1A: Response inhibition and positive/arousal associations.* We hypothesized that individuals with weak response inhibition would show stronger positive relations between implicit positive/arousal associations and alcohol consumption, but weaker relations between explicit positive/arousal associations and alcohol consumption.

*Hypothesis 1B: Response inhibition and relaxation associations.* We hypothesized that individuals with weak response inhibition would show stronger positive relations between implicit relaxation associations and alcohol consumption, but weaker relations between explicit relaxation associations and alcohol consumption.

*Hypothesis 2A: Working Memory and positive/arousal associations.* We hypothesized that individuals with poor WM capacity would show stronger positive relations between implicit positive/arousal associations and alcohol consumption, but weaker relations between explicit positive/arousal associations and alcohol consumption.

*Hypothesis 2B: Working Memory and relaxation associations.* We hypothesized that individuals with poor WM capacity would show stronger positive relations between implicit relaxation associations and alcohol consumption, but weaker relations between explicit relaxation associations and alcohol consumption.

## MATERIALS AND METHODS

### Sample and recruitment

Participants were recruited from a midsize public university in the northeastern USA. Data were collected from 273 participants in

spring and fall semesters of 2011. After excluding participants who had never consumed alcohol, had a diagnosis of ADHD or a history of head injury with loss of consciousness for at least 15 minutes, our final sample consisted of 205 participants who were on average 19.0 years old (standard deviation (SD) = 1.1) and mostly female ($n$ = 150, 73.2%). Most participants were white ($n$ = 162, 79.8%), followed by other ($n$ = 16, 7.9%), more than one/mixed ($n$ = 12, 5.9%), black ($n$ = 9, 4.4%) and Asian ($n$ = 4, 2.0%). There were 28 (13.7%) Hispanic/Latino participants. Course instructors offered extra class credit for voluntary participation. As an additional incentive, we offered participants a chance to win one of 100 gift cards valued at $10 to purchase music. The study protocol was approved by the Institutional Review Board at the University of Rhode Island.

## Procedure

Participants first provided written informed consent for anonymous participation. Participants completed three tests of inhibition in random order, followed by positive/arousal and relaxation implicit association tasks (IATs) in counterbalanced order. We then administered questionnaires. Finally, participants were debriefed.

## Measures

### Alcohol consumption

Alcohol consumption was explicitly assessed with Timeline Follow-back method, considered one of the most reliable and valid approaches for assessing alcohol consumption (Sobell and Sobell, 1992). Participants were asked to indicate the number of drinks they consumed each day for the previous 30 days, with the aid of a calendar. Three indicators of alcohol consumption were derived, including average weekly number of drinks, number of gender-specific heavy drinking episodes in the previous 30 days (defined as five or more drinks on one occasion for a male and 4 of more drinks on one occasion for a female) and maximum number of drinks on one occasion during the previous 30 days.

### Alcohol-related problems

Alcohol-related problems were explicitly assessed using the Brief Young Adult Alcohol Consequences Questionnaire (B-YAACQ; Kahler *et al.*, 2005). The B-YAACQ is a 24-item questionnaire with a dichotomous response format that assesses a broad range of alcohol-related problems experienced by college students in the previous year. A sample item is 'I have passed out from drinking.' Response options were coded so that 0 = 'no' and 1 = 'yes'. A single score was calculated by summing responses across all items with higher values indicating greater problems. Coefficient alpha for our sample was 0.82.

### Implicit alcohol associations

Among the most commonly utilized tools in the assessment of implicit associations is the IAT (Greenwald *et al.*, 1998). The IAT is a computerized reaction time test in which participants are asked to categorize target (e.g. liquor, rum, wine, vodka, beer, tequila; labeled as 'alcohol') and non-target stimuli (e.g. water, milk, coffee, Gatorade, soda, tea; labeled as 'not alcohol') as quickly as possible. The rationale behind the IAT is that response times are faster when participants are asked to categorize stimuli in ways compatible with their implicit views. Participants completed two IATs. The first IAT (hereafter referred to as the positive/arousal IAT) was in a bipolar format to assess positive/arousal (e.g. talkative, funny, happy, excited, confident and brave) vs. negative/sedation (e.g. withdrawn, miserable, sad, depressed, sick and down) implicit associations. Participants also completed a unipolar IAT to assess positive/sedating (e.g. relaxed, calm, peaceful, tranquil, carefree and comfortable) vs. neutral (e.g. average, normal, general, ordinary, typical and usual) words and their implicit associations with alcohol (herein referred to as the relaxation IAT; Ames *et al.*, 2013). Selection of IAT and alcohol stimuli was based on previous research (Fromme *et al.*, 1993; Thush *et al.*, 2008; Houben *et al.*, 2010) and with examination of pilot tested word ratings from 25 undergraduate students. The format of the IATs was identical to those used in related research (Houben and Wiers, 2009). We calculated D-measure scores for the IAT using the improved algorithm described in Greenwald *et al.* (2003, p. 214; table 4; following steps from Column 'Improved Algorithm'). Internal consistency among the practice and test combination blocks was 0.69 for the positive/arousal IAT and 0.64 for the relaxation IAT.

### Explicit alcohol expectancies

Arousing and sedating alcohol expectancies were assessed consistent with previous related work (Thush *et al.*, 2008). Specifically, 18 unipolar positive/arousing items matching the positive/arousal IAT (12 items; 'Alcohol makes me feel energetic') and the relaxation IAT (6 items; 'Alcohol helps me feel relaxed'). Response options range from 0 = 'strongly disagree' to 4 'strongly agree.' Coefficients alpha were 0.87 and 0.82 for the positive/arousal and relaxation expectancy scales, respectively.

## Executive functions measures

### Response Inhibition

Response inhibition was assessed using computerized version of the reliable and well-validated Stroop Color and Word Test (Stroop, 1935). The Stroop test measures the ability to inhibit an automatic response. The format of the Stroop test was identical to those used in related research (Houben and Wiers, 2009). Briefly, participants must respond with the color of stimuli. In the practice block, 48 stimuli with no meaning (e.g. ####, &&&&) are presented. In the test block, 48 words are themselves colors (e.g. letters spelling 'yellow', 'red') such that 24 trials are compatible (word matches word color) and 24 trials are incompatible (word is another color). A single score was calculated to measure response inhibition by subtracting the number of errors on incompatible trials from the number of errors on compatible trials. Thus, higher levels on this measure indicate greater inhibition ability.

### WM capacity

WM capacity was assessed using the Letter–Number (L-N) sequencing subtest of the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2008). In the L-N task, participants were read a string of numbers and letters and were asked to repeat the numbers first, in ascending order, followed by the letters, in alphabetical order.

# RESULTS

## Alcohol consumption and problems

On average, female participants drank 4.5 standard drinks per week (SD = 5.2) while men drank 7.8 (SD = 7.2). The maximum number of drinks per day in the past 30 days by female participants was 4.8 (SD = 4.1) and for men it was 8.3 (SD = 6.1). Female participants had on average 2.5 heavy drinking days in the previous 30 days (SD = 3.4). For male participants, there was an average of 3.2 heavy drinking days (SD = 3.1). Of note, 89% of female and 96% of male

participants reported experiencing at least one problem in the previous 12 months.

## Model specification

### Confirmatory factor analysis

Confirmatory factor analysis was conducted to examine the constructed alcohol consumption latent variable. Alcohol consumption was estimated with three log-transformed indicators of alcohol consumption (e.g. average weekly number of drinks, frequency of heavy drinking episodes and peak number of drinks) and one indicator of alcohol-related problems and displayed good fit, $\chi^2(2; N = 205) = 7.81$, $P < 0.05$, Comparative Fit Index (CFI) = 0.99, Non-normed Fit Index (NNFI) = 0.98, Standardized Root Mean Square Residual (SRMR) = 0.02. The Root Mean Square Error of Approximation (RMSEA) was elevated with a value of 0.12. The model exhibited acceptable levels of fit across indices with exception to the RMSEA. We decided to retain this model given the acceptable levels of fit across most indices.

### Test of study hypotheses

In order to test our substantive hypotheses, we estimated four structural equation models using maximum likelihood estimation that incorporated measured (manifest) and unmeasured (latent) variables. In Model 1, we examined the moderating effect of response inhibition on positive/arousal associations as predictors of alcohol consumption. As recommended (Aiken and West, 1991), the variables comprising the interaction term were centered, making main effects interpretable in the context of interactions (Cohen *et al.*, 2003). Monte Carlo simulation analyses in Mplus 7 (Muthén & Muthén, 2012) indicated that given our sample size, we were sufficiently powered (95% confidence interval (CI) = 0.93–0.95) to detect a small-sized interaction effect in the presence of main effects of all covariates. Model 2 was identical to Model 1 with relaxation associations in place of positive/arousal associations and interaction terms adjusted correspondingly. Models 3 and 4 had WM replacing response inhibition from Models 1 and 2. If the interaction path was significant, the presence of moderation of inhibition ability was explored using simple slope analysis (Aiken and West, 1991).

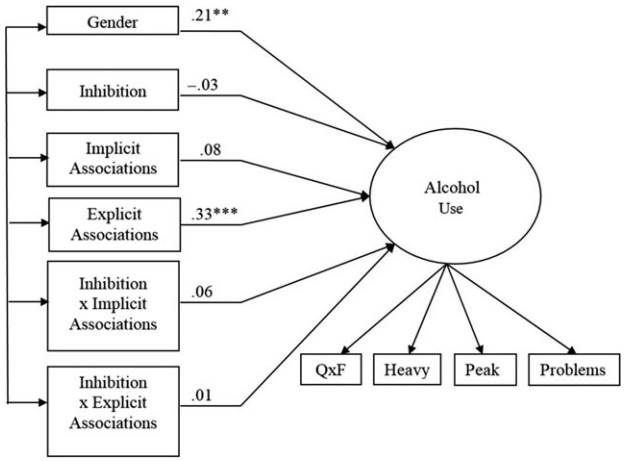


**Fig. 1.** Model 1: Positive/arousal associations and inhibition structural equation model.
*Note:*** $P < 0.01$, *** $P < 0.001$

*Hypothesis 1 A: Positive/arousal associations and inhibition.* In the first model, we examined relations among inhibition abilities, positive/arousal implicit associations and positive/arousal expectancies (Fig. 1). Results indicated good model fit, $\chi^2(20; N = 205) = 52.26$, $P < 0.001$, CFI = 0.96, NNFI = 0.91, although the RMSEA = 0.09 was slightly elevated. After controlling for correlations among exogenous variables (Table 1), main effects of gender ($\beta = 0.21$, $P < 0.01$, 95% CI = 0.08–0.33) and positive/arousal expectancies ($\beta = 0.33$, $P < 0.001$, 95% CI = 0.21–0.46) on alcohol consumption were observed, such that men reported significantly higher levels of alcohol consumption than women. Significant interactions were not observed between inhibition and positive/arousal implicit associations or between inhibition and positive/arousal expectancies. Thus, support for Hypothesis 1 A was not obtained. Results of $R^2$ indicate that 16% of the variance in alcohol consumption was explained by the model.

*Hypothesis 1B: Relaxation associations and inhibition.* In the second model, we examined relations among response inhibition, relaxation implicit association and relaxation expectancies (Fig. 2). Results indicated good model fit, $\chi^2(20; N = 205) = 36.60$, $P < 0.05$, CFI = 0.98, NNFI = 0.95 and RMSEA = 0.06. Results of $R^2$ indicate that 14% of the variance in alcohol consumption was explained by the model. After controlling for correlations among exogenous variables (Table 1), main effects were observed for gender ($\beta = 0.21$, $P < 0.01$, 95% CI = 0.09–0.34), with men reporting higher levels of alcohol consumption and relaxation expectancies ($\beta = 0.28$, $P < 0.001$, 95% CI = 0.15–0.41). Additionally, stronger relaxation implicit associations and stronger relaxation expectancies were associated with greater levels of alcohol consumption. Relaxation implicit associations were only marginally related ($\beta = 0.14$, $P < 0.01$, 95% CI = −0.01 to 0.30). A significant interaction effect between inhibition

**Table 1.** Pearson product moment correlations among predictor and outcome variables

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Gender | — | | | | | | | | | | |
| 2. WM | 0.24*** | — | | | | | | | | | |
| 3. Inhibition | 0.02 | 0.10 | — | | | | | | | | |
| 4. IAT positive/arousal | 0.06 | −0.03 | −0.08 | — | | | | | | | |
| 5. IAT relaxation | 0.02 | −0.05 | −0.06 | 0.03 | — | | | | | | |
| 6. Positive/arousal expectancies | −0.06 | 0.04 | 0.04 | −0.08 | −0.02 | — | | | | | |
| 7. Relaxation expectancies | −0.05 | 0.00 | 0.10 | −0.04 | −0.01 | 0.58**** | — | | | | |
| 8. Quantity-frequency | 0.24*** | 0.09 | 0.00 | 0.09 | 0.11 | 0.26*** | 0.21** | — | | | |
| 9. Heavy drinking | 0.09 | 0.08 | 0.05 | 0.07 | 0.08 | 0.26*** | 0.20** | 0.90**** | — | | |
| 10. Maximum drinks | 0.31**** | 0.11 | −0.06 | 0.11 | 0.18* | 0.25*** | 0.21** | 0.80**** | 0.63**** | — | |
| 11. Alcohol problems | 0.10 | 0.16* | 0.10 | 0.07 | −0.03 | 0.38**** | 0.28**** | 0.48**** | 0.45**** | 0.45**** | — |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, **** $P < 0.0001$.

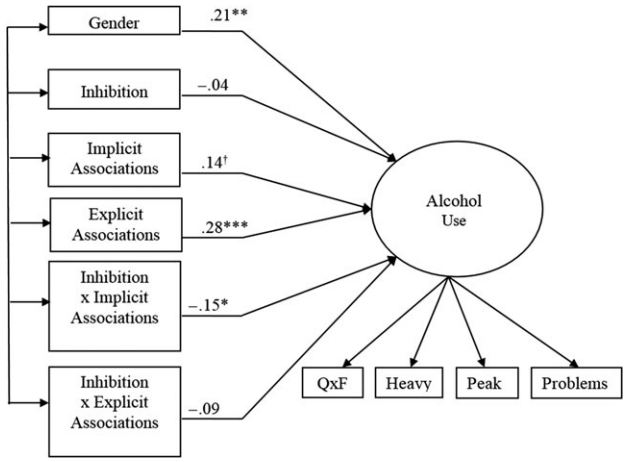


**Fig. 2.** Model 2: Relaxation associations and inhibition structural equation model.
*Note:* $^{\dagger}P < 0.05$ (one-tailed), $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

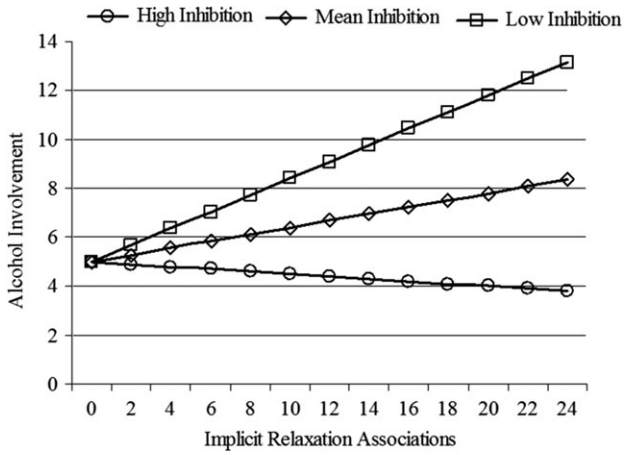


**Fig. 3.** Implicit relaxation associations and inhibition.
*Note:* Relations between implicit relaxation associations and alcohol consumption at low, medium and high levels of inhibition.

and relaxation implicit associations was observed ($\beta = -0.15$, $P < 0.05$, 95% CI = −0.29 to −0.01). As depicted in Fig. 3, at lower levels of inhibition, the relation between implicit relaxation associations and alcohol consumption was significant ($\beta = 0.34$, $P < 0.05$, 95% CI = 0.09–0.59), while at higher levels it was not ($\beta = -0.05$, $P > 0.05$, 95% CI = −0.23 to 0.13). Thus, consistent with Hypothesis 1B, individuals with weaker response inhibition demonstrated stronger relations between implicit associations and alcohol consumption. A significant interaction effect between inhibition and relaxation expectancies was not observed. Thus, support for hypotheses about interaction with explicit associations was not obtained.

*Hypotheses 2a and 2b: Working Memory and positive/arousal, relaxation associations.* Additional structural equation models were estimated with WM capacity in the place of response inhibition to determine if WM capacity would moderate relations between alcohol associations and alcohol consumption. Both models fit the data well (WM × Positive/Arousal Associations: $\chi^2(20; N = 205) = 37.60$, $P < 0.05$, CFI = 0.98, NNFI = 0.95 and RMSEA = 0.07; WM × Relaxation Associations: : $\chi^2(20; N = 205) = 30.53$, $P < 0.05$, CFI = 0.99, NNFI = 0.97 and RMSEA = 0.05). Fig. 4 shows the results from these analyses. Results of parallel models did not reveal significant interaction effects between WM capacity and any of the alcohol cognitions tested nor main effects for WM capacity or implicit associations. This indicates that support for Hypotheses 2 A and 2B was not obtained.

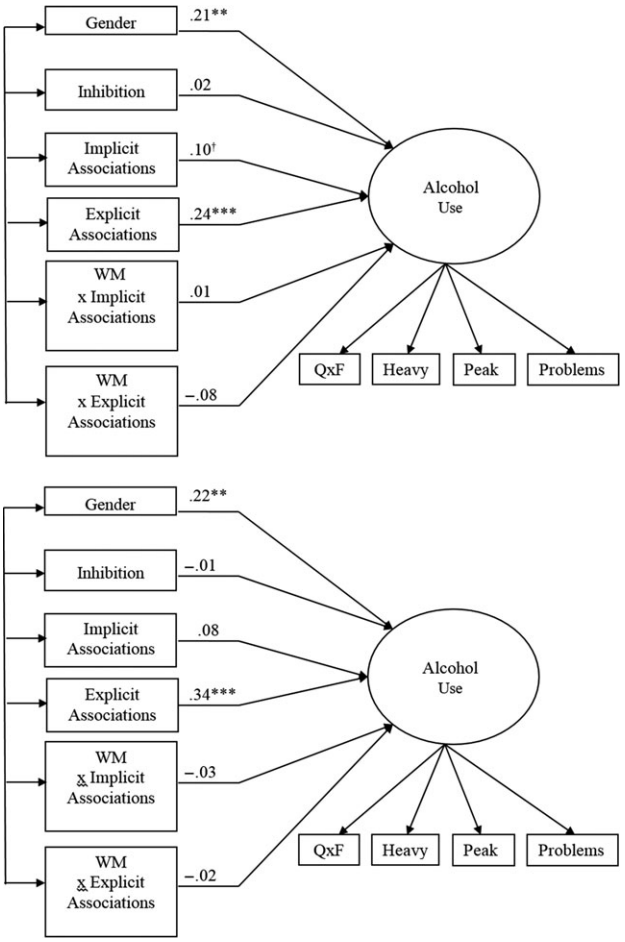


**Fig. 4.** Models 3 and 4: Positive/arousal (top), relaxation (bottom) associations and WM.
*Note:* $^{\dagger}P < 0.1$, $^{**}P < 0.01$, $^{***}P < 0.001$.

## DISCUSSION

In this research, we studied relations among alcohol associations, inhibition and alcohol consumption. We found that individuals with stronger response inhibition showed weaker relations between relaxation implicit associations and alcohol consumption, which suggests that individuals with stronger response inhibition may be better able to inhibit automatic alcohol-related associations that have been primed by environmental cues, compared to individuals with lower response inhibition. However, we did not find similar hypothesized effects for the moderating role of WM, nor did we find a moderating role for response inhibition in the effects of implicit positive/arousal associations on alcohol consumption. These findings suggest that response inhibition abilities are important for understanding variability in how implicit associations affect alcohol consumption,

although the exact conditions of this function remains to be determined.

Results from this study are somewhat similar to earlier work by Grenard *et al.* (2008) and Thush *et al.* (2008), identifying a moderating role of WM supporting the reflective system in the link between impulsive processes and alcohol consumption behavior. Similar to earlier work, in college students, there does not appear to exist a population-wide main effect of implicit associations on alcohol consumption (Peeters *et al.*, 2013; Pieters *et al.*, 2014). Rather, effects of implicit associations appear to be specific to a subpopulation placed at risk by inability to regulate impulses effectively. Indeed, previous studies on populations identified as at risk for maladaptive behavior (Peeters *et al.*, 2012, 2013) showed main effects of alcohol-specific associations on drinking behavior. This study differed from earlier work in that the sample was predominantly female and relatively light-drinking. Compared to earlier work, we found moderate relations between relaxation associations rather than the more common positive/arousal associations. These findings may be attributed to the notion that female drinkers more commonly report coping motives as reasons for drinking, suggesting that relaxation and relief from negative affect is a more common objective. As such, more such associations could have formed over time in the current sample. Nevertheless, this study has multiple failures to replicate prior results on the moderating role of WM capacity, which bear further scrutiny in future research. There was a lack of support for hypotheses regarding interaction between explicit arousal and relaxation associations and response inhibition or WM, which is in contrast to the findings of Thush *et al.*, 2008. Potentially, a restriction of range for response inhibition or WM contributed to a failure to identify moderation by these mechanisms.

There are numerous strengths to this research, including a relatively large sample size and the use of structural equation modeling, which allowed us to examine alcohol outcomes as a latent variable. In this research, we conducted a more conservative test of relations between implicit associations and alcohol consumption by controlling for relations with expectancies (compared to Thush *et al.*, 2008). Additionally, our college sample may not reflect the ordinary distribution of inhibition factors of this age group and beyond. Future studies including non-college members of this age group may clarify whether this restriction of range influenced our lack of support for moderation of explicit associations. This research is the first in this area to examine multiple domains of inhibition while assessing both implicit and explicit alcohol cognitions within a single study. However, several limitations to this study should also be noted. Our sample is predominantly female, although gender was controlled for in analyses. Results obtained from the current sample may also not generalize to population that differ in terms of drinking level, as our sample consisted of relatively low-drinking college students. Additional limitations to our findings result from the correlational, cross-sectional design of the study. Results are further limited because not all assessments were implicit, meaning that self-report biases may have affected explicit assessments of alcohol consumption and associations. Self-report biases may have caused the relations between explicit associations and alcohol consumption to be understated. Future research may benefit from using *in vivo* assessments of alcohol consumption (see Monk *et al.*, 2016).

## CONCLUSION AND FUTURE DIRECTIONS

While this study provides mixed support for a moderating role of inhibition functions on alcohol associations and use, it remains clear that this avenue of research should continue to receive attention as findings can inform preventive intervention approaches. Specifically, the utility in strengthening response inhibition, altering implicit alcohol associations, and altering alcohol expectancies warrant further exploration. Surprisingly, our findings show that interactions between implicit associations and response inhibition, not WM, were supported. This is despite earlier findings from Thush *et al.* (2008) supporting interactions with WM, with response inhibition being the previously untested moderator. Earlier research by Peeters *et al.* (2013) has demonstrated that both response inhibition and WM may be predictive of onset of substance use, and as such, future research must replicate these findings to determine whether response inhibition is indeed a moderating trait. To date, research has provided promising initial support for the utility of strengthening response inhibition to reduce alcohol consumption in heavy drinkers (Houben *et al.*, 2011).

Future research should continue to disentangle the components of inhibition training that can result in meaningful changes in drinking behavior. Taken together with the potential malleability of implicit associations (Houben *et al.*, 2010; Wiers *et al.*, 2011) and expectancies (Wood *et al.*, 2007), these findings offer promise for tailored interventions for alcohol misuse. Preventive efforts could be enhanced for those at risk for alcohol consumption disorders, by incorporating inhibition skills strengthening into their treatment in addition to addressing their alcohol-related cognitions. Future research employing longitudinal designs will allow for greater understanding of how inhibition abilities and cognitive associations predict future drinking. Future research should also be conducted in an effort to replicate these findings with community samples of college-age participants, particularly heavy drinking students with a more even gender distribution, students with diverse cognitive abilities and students with psychopathology affecting inhibition functions, to better determine both the parameters of these moderating effects and how broadly these findings generalize.

## FUNDING

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## CONFLICT OF INTEREST STATEMENT

None declared.

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