

Cognitive Regulation of Craving in Alcohol-Dependent and Social Drinkers

Nasir H. Naqvi, Kevin N. Ochsner, Hedy Kober, Alexis Kuerbis, Tianshu Feng, Melanie Wall, and Jon Morgenstern

Background: Helping alcohol-dependent individuals to cope with, or regulate, cue-induced craving using cognitive strategies is a therapeutic goal of cognitive behavioral therapy (CBT) for alcohol dependence. An assumption that underlies this approach is that alcohol dependence is associated with deficits in such cognitive regulation abilities. To date, however, the ability to utilize such strategies for regulation of craving has never been tested in a laboratory setting.

Methods: Here we compared 19 non-treatment-seeking, alcohol-dependent drinkers (AD) to 21 social drinkers (SD), using a laboratory task that measured the ability to reduce cue-induced alcohol craving by thinking about long-term negative consequences of drinking, which is a specific cognitive regulation strategy that is taught in CBT. The task also assessed the ability to reduce food craving elicited by high-calorie food cues using a similar strategy.

Results: The reduction in craving when using this cognitive regulation strategy was approximately double in SD, compared to AD, for both alcohol and food cues. Furthermore, in SD but not AD, the ability to regulate cue-induced alcohol craving was correlated with the ability to regulate food craving. There were no significant correlations found between the ability to regulate cue-induced alcohol craving and a number of self-report measures related to severity of alcohol dependence, baseline craving, impulsivity, and general self-regulation ability, for either AD or SD.

Conclusions: The results suggest that alcohol dependence is associated with deficits in cognitive regulation of cue-induced craving and that these deficits are not specific to the regulation of alcohol craving, but generalize to the regulation of other appetitive states, such as food craving. Future studies may use similar procedures to address the neural and cognitive processes that underlie such regulation deficits, as well as the effects of treatments such as CBT on these processes.

Key Words: Craving, Self-Regulation, Coping Skills, Cue-Exposure, Cognitive Behavioral Therapy.

A hallmark of alcohol dependence is craving, or the strong subjective desire to drink (A.P.A., 2013). Cognitive behavioral therapies (CBTs) for alcohol dependence, such as cognitive behavioral coping skills therapy and relapse prevention therapy, teach alcohol-dependent individuals to “cope” with craving when faced with temptations to drink using a variety of cognitive strategies. Such strategies include “challenging and changing” thoughts about alcohol by focusing on long-term, negative consequences of drinking instead of short-term, pleasurable consequences (Kadden, 2007). This is part of a broader approach employed by CBT, aimed at teaching strategies for self-regulating affective states that promote relapse, such as craving and nega-

tive affect. According to the theoretical framework underlying CBT for addiction disorders (Larimer et al., 1999), alcohol-dependent individuals possess deficits in their intrinsic coping ability and use alcohol as a maladaptive coping strategy to compensate for these deficits. In keeping with this account, deficits in coping ability have been identified in alcohol-dependent individuals using self-report scales (Berking et al., 2011). However, attempts to relate the mechanism of CBT to the remediation of self-reported coping skills deficits have been largely unsuccessful (Morgenstern and Longabaugh, 2000). This may be due to limitations inherent in clinical self-report scales, such as recall bias and poor reliability, as well as a lack of specificity *vis-à-vis* the psychological processes that underlie a complex construct such as coping ability (Morgenstern et al., 2013). Laboratory measures allow for a finer-grained, real-time parsing of the multiple cognitive, affective, motivational, and, ultimately, neural processes that underlie coping, how these processes are disrupted by alcohol dependence, and their role in treatment (Ochsner, 2008; Ochsner et al., 2012).

Cue-induced craving is a specific form of craving triggered by stimuli that have been previously associated with alcohol (Niaura, 2000). Cue-induced craving occurs in “high-risk” situations where relapse tends to occur, such as social settings where alcohol is being consumed, and is thus a focus of

From the Department of Psychiatry (NHN, AK, TF, MW, JM), Columbia University, New York, New York; Department of Psychology (KNO), Columbia University, New York, New York; and Department of Psychiatry (HK), Yale University, New Haven, Connecticut.

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Reprint requests: Nasir H. Naqvi, MD, PhD, Department of Psychiatry, Division on Substance Abuse, Columbia University, Box 66 (STARS), 1051 Riverside Drive, New York, NY 10032; Tel.: 914-255-2842; Fax: 914-470-9453; E-mail: nhn2102@columbia.edu

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coping skills training in CBT for addictions (Kadden, 2007). Although the specific role of cue-induced craving in compulsive drinking and relapse is a matter of debate (Tiffany and Conklin, 2000), cue-induced craving is a widely studied laboratory phenomenon, associated with a well-characterized set of subjective, behavioral, autonomic, and neural responses (Carter and Tiffany, 1999; Schacht et al., 2013). While previous laboratory studies have addressed how cue-induced alcohol craving is modulated by various psychological factors, such as opportunities to drink (Wilson et al., 2004), expectancies of alcohol's hedonic effects (Carter, 2006), and mood (Rubonis et al., 1994), no laboratory study yet has examined how cue-induced alcohol craving is affected by the utilization of cognitive coping strategies.

Coping with cue-induced alcohol craving using cognitive strategies, such as thinking about long-term, negative consequences of drinking instead of short-term, positive consequences, is a form of cognitive emotion regulation. Specifically, an emotionally charged stimulus (an alcohol cue) is thought about in a way that changes its semantic associations (pleasure, enjoyment, relaxation vs. illness, conflict, depression), altering its emotional impact (the incentive value alcohol), leading to a reduction in the level of felt emotion (subjective craving). A large number of functional neuroimaging studies have provided converging evidence that cognitive regulation of negative emotions, such as fear, sadness, and disgust, increases activity in prefrontal cortical regions involved in various aspects of cognitive control, leading to a down-modulation of activity in subcortical regions involved in triggering affective and motivational states, which in turn leads to a reduction in emotional response (reviewed in Ochsner et al., 2012). This prefrontal circuitry has also been shown to play a role in the cognitive regulation of appetitive emotions, including cue-induced cigarette craving (Kober et al., 2010b), cue-induced cocaine craving (Volkow et al., 2010), and cue-induced food craving (Yokum and Stice, 2013). Neuropsychological and functional neuroimaging studies have shown that alcohol dependence is associated with abnormalities in this circuitry that are correlated with impairments in fundamental self-regulatory processes that may underlie cognitive emotion regulation in general and cognitive regulation of craving specifically. These include conflict monitoring (Field et al., 2007), response inhibition (Bjork et al., 2004; Lawrence et al., 2009), reward learning (Sjoerds et al., 2013), delayed discounting (Field et al., 2007), and reward-based decision-making (Xiao et al., 2013). Thus, if the ability to cognitively regulate cue-induced alcohol craving is dependent upon the integrity of this neural circuitry, then it is likely that alcohol dependence is associated with impairments in this ability.

In this study, we employed a laboratory task that indexed subjects' ability to reduce cue-induced alcohol craving by thinking about negative consequences of drinking, which is a specific coping/cognitive regulation strategy that is taught in CBT for alcohol dependence. The task was adapted from previous studies in cigarette smokers examining their ability to

cognitively regulate cue-induced cigarette craving (Kober et al., 2010a,b). We compared performance on this task between a group of alcohol-dependent drinkers (AD) and a group of social drinkers (SD) who were matched on a number of demographic variables. The task included high-calorie food cues in addition to alcohol cues, to control for general regulation processes that modulate all appetitive emotional states, not just those that regulate cue-induced alcohol craving. We addressed 3 hypotheses: (i) thinking about long-term, negative consequences of drinking will reduce cue-induced alcohol craving; (ii) AD will be relatively impaired in this form of cognitive regulation of craving, compared to SD; and (iii) this impairment will be specific to alcohol cues, that is, it will not affect regulation of cue-induced food craving. To understand the sources of variability in regulation ability among AD, we also performed exploratory analyses examining the correlations between individual differences in the ability to cognitively regulate alcohol craving and self-report measures of heavy drinking, alcohol dependence severity, baseline alcohol craving, impulsivity, and self-regulation.

MATERIALS AND METHODS

Participants

Nineteen individuals with AD and 21 SD were recruited as follows: Advertisements were posted in the local community inviting "individuals who drink alcohol" to undergo "tests of decision making." Participants underwent brief telephone screening, to ascertain basic demographics and the quantity of drinking. Treatment seekers were excluded. For recruitment purposes, participants were initially categorized as heavy drinkers (>14/24 drinks per week for women/men) or light drinkers (<15/25 drinks per week for women/men) and invited to participate based upon their age, sex, and education level to facilitate matching between groups. After providing informed consent, participants underwent the Composite International Diagnostic Interview-Substance Abuse Module (CIDI-SAM; Robins et al., 1988). Participants were then categorized as either AD or SD using the results of the CIDI-SAM. Specifically, AD were defined as participants meeting DSM-IV criteria for alcohol dependence during the last year, according to the CIDI-SAM, while SD were defined as participants not meeting DSM-IV criteria for either alcohol dependence or alcohol abuse, irrespective of the quantity of alcohol consumed. Participants with other DSM-IV substance use disorders, with the exception of nicotine dependence, were excluded using the CIDI-SAM. Participants with psychotic and bipolar disorders were excluded using the Structured Clinical Interview for DSM Disorders (First et al., 1997). Participants with severe current depression or anxiety were excluded using the Beck Depression Inventory (BDI; Beck et al., 1961; score > 29) and the Beck Anxiety Inventory (BAI; Beck et al., 1988; score > 29), respectively. Participants were excluded if they were cognitively impaired according to the Folstein Mini-Mental State Exam (MMSE; Folstein et al., 1975; score < 24). Participants were excluded if they were intoxicated or were in moderate to severe alcohol withdrawal, based on breath alcohol test (estimated blood alcohol level > 0.05) and the Clinical Institute for Withdrawal from Alcohol Assessment-Revised (Sullivan et al., 1989; score > 9), respectively. Participants were also excluded if they were currently taking any psychoactive medications; had a history of severe medical complications of alcohol dependence (e.g., cirrhosis, withdrawal seizures, or delirium tremens); had a history of violence or suicide attempts, psychiatric hospitalization within the last year; or were homeless.

Baseline Assessments

All participants were administered the 90-day Timeline Follow-back Interview (Sobell et al., 1979), from which were derived the number of standard drinks per week (DPW) and the percent of heavy-drinking days (%HDD, calculated as percent of days consuming >5/4 drinks for men/women over 90 days). They also completed the Alcohol Dependence Severity Scale (past 12 months) (ADS; Skinner and Allen, 1982), the Obsessive Compulsive Drinking Scale (previous 30 days) (OCDS; Anton et al., 1995), the Barratt Impulsiveness Scale (current state) (BIS; Patton et al., 1995), the Short Self-Regulation Questionnaire (current state) (SSRQ; Carey et al., 2004), and the Alcohol Urge Questionnaire (current state) (AUQ; Bohn et al., 1995).

Regulation of Craving Task

All participants completed the Regulation of Craving (ROC) task. In this task, participants were presented 50 pictures of alcoholic beverages and 50 pictures of high-calorie foods in pseudorandom order. All pictures were obtained from a high-quality stock photo Web site (123rf.com) and had previously been rated as eliciting moderate to high levels of craving in an earlier pilot experiment in AD (unpublished data). None of the pictures contained people, as the presence of people had been shown in this same pilot experiment to result in lower craving levels. Each trial began with a fixation cross (4.5 seconds), followed by a regulation instruction (NOW or LATER; 2 seconds), followed by the cue picture (ALCOHOL or FOOD; 6 seconds), followed by a fixation cross (3.5 seconds), followed by an instruction to rate their craving "How much do you want this item?" on the computer keyboard using a 1 to 5 Likert scale (rating period terminated by key press, maximum 6 seconds duration). The order of the stimuli and the regulation conditions were randomized, with approximately equal numbers of 4 trial types: NOW/ALCOHOL, LATER/ALCOHOL, NOW/FOOD, and LATER/FOOD. The task was programmed and presented on a laptop computer using E-Prime software (Psychology Software Tools, Sharpsburg, PA).

Prior to the task, participants were informed that the study was examining the way in which thinking about positive and negative consequences can change the desire to consume alcohol and food, respectively. They were then asked to describe some long-term, negative consequences and short-term, pleasurable consequences of consuming alcohol and high-calorie foods, respectively. They were then instructed on the ROC task, including being told what to do when they saw the "LATER" and "NOW" cues. Specifically, they were instructed that on trials when they received the LATER instruction, they were to recall long-term, negative consequences of repeatedly consuming the depicted item (alcohol or high-calorie food, respectively); on trials when they received the NOW instruction, they were to recall the immediate, pleasurable consequences of consuming the depicted item right now. They were not instructed to reduce or increase their craving for any of the conditions, that is, regulation of craving was not an explicit goal of the task. They then completed 4 practice trials, during which they were asked to verbalize the LATER and NOW strategies for each trial to confirm that they understood the task instructions. The total time to complete the ROC task was approximately 20 minutes. Following the completion of the task, participants were debriefed to confirm that they continued to understand the task instructions throughout the entire task.

Data Analysis

Demographic variables (age, sex, education), measures of the heavy drinking (DPW and %HDD), and baseline self-report psychological measures (the MMSE, the BIS, the ADS, AUQ, OCDS, and SSRQ) were collected. The OCDS subscales for resistance,

obsession, and interference (Roberts et al., 1999) were also calculated. All of these variables were compared between AD and SD groups using *t*-tests for normally distributed variables, or Mann-Whitney *U*-tests for non normally distributed variables. To address the potential effects of using heavy-drinking status for recruitment/matching purposes, we also calculated the number of participants in the AD and SD groups who were initially classified as light drinkers or heavy drinkers, respectively.

For each subject, the craving rating made after each trial was averaged across all of the trials of the same type (4 trial types: NOW/ALCOHOL, LATER/ALCOHOL, NOW/FOOD, and LATER/FOOD). A mixed-effects model was used to examine within-subject effects of cue type (ALCOHOL vs. FOOD) and regulation instruction (LATER vs. NOW), between-subject effects of group (AD vs. SD), and all 2- and 3-way interactions among within- and between-subject effects. Baseline BAI and BDI were included as control variables in the mixed-effects model. The 3-way interaction provided a test of whether AD versus SD differed in the contrast between how they regulated their alcohol cravings versus how they regulated food cravings (i.e., the specificity of regulation deficits in AD vs. SD to alcohol craving). When the 3-way interaction was found not to be significant, a reduced model including only the 2-way group (AD vs. SD) by regulation (NOW vs. LATER) interaction in the model was rerun, which provided a test of whether AD versus SD differed in how they regulated their cravings, regardless of cue type. Post hoc *t*-tests were used to test for significant differences in self-reported craving within each group between the NOW and LATER conditions, collapsed across FOOD and ALCOHOL cues. Similar post hoc tests were conducted to test for significant differences in self-reported craving within each group between alcohol and food cues, collapsed across the NOW and LATER conditions. All significance levels were Bonferroni-adjusted for multiple comparisons. Effect sizes (ES) were also estimated using Cohen's *d*, correcting for the correlation between repeated measures (Morris and DeShon, 2002).

For each subject, a measure of regulation success was calculated by subtracting the average rating for the LATER trials from the average rating for the NOW trials. This was performed separately for ALCOHOL and FOOD cues. Correlations were performed to examine relationships between individual differences in regulation ability for ALCOHOL cues and individual differences in regulation ability for FOOD cues. This was performed separately for AD and SD. A regression of regulation ability for food on regulation ability for alcohol, group, and their interaction was performed to test for differential associations between regulation abilities by group. Additionally, correlations between regulation ability and measures of heavy drinking (DPW, %HDD) and baseline self-report measures (BIS, ADS, AUQ, OCDS, and SSRQ) were performed separately for ALCOHOL cues only. These correlations were performed separately for AD and SD. Pearson correlation or Spearman correlation was used, depending on whether the variables were normally or non normally distributed, respectively. Alpha levels were Bonferroni-adjusted for multiple correlations.

RESULTS

Comparing AD and SD on Demographic and Baseline Measures

Table 1 shows that AD and SD were not significantly different with respect to sex, age, and level of education. Table 2 shows that AD had significantly higher DPW and %HDD, higher scores on the ADS and AUQ, as well as the BDI. There was a trend toward a higher BAI score in AD

Table 1. Demographic Variables, Comparing Alcohol-Dependent (AD) and Social Drinkers (SD)

Variable	AD (N = 19)	SD (N = 21)	p-Value
N male (%)	12 (63)	16 (76)	0.49 (χ^2)
Age	36.7 ± 9.1	34.7 ± 9.5	0.55
Education completed			0.73 (χ^2)
Grade school	0	1	
High school	11	10	
College	5	7	
Graduate school	3	3	

Age compared using Mann-Whitney *U*-test. Frequencies compared using χ^2 test. No significant differences were found between groups. Significance levels not adjusted for multiple comparisons.

Table 2. Baseline Clinical and Psychological Variables in Alcohol-Dependent (AD) and Social Drinkers (SD)

Variable	AD (N = 19)	SD (N = 21)	p-Value
DPW	35.7 ± 14.4	12.5 ± 13.1	<0.001*
%HDD	35.8 ± 20.2	13.81 ± 22.3	<0.001*
ADS	10.7 ± 6.1	4.2 ± 2.8	<0.001*
AUQ	30.0 ± 10.6	22.3 ± 4.38	<0.01*
OCDS (total)	18.47 ± 15.09	18.76 ± 19.55	0.10
Obsession factor	4.42 ± 2.92	4.04 ± 3.77	0.73
Interference factor	1.89 ± 4.35	3.00 ± 4.34	0.37
Resistance factor	1.93 ± 1.57	1.91 ± 1.95	0.97
BIS	33.4 ± 8.5	35.2 ± 7.5	0.197
SSRQ	99.79 ± 9.40	98.71 ± 8.08	0.75
BDI	14.1 ± 12.3	5.4 ± 7.3	<0.01*
BAI	9.2 ± 11.1	3.8 ± 6.0	0.014
MMSE	28.7 ± 1.4	29.2 ± 1.0	0.254

*Significant difference between SD and AD, adjusting alpha levels for multiple comparisons.

DPW, drinks per week; %HDD, percent heavy-drinking days; ADS, Alcohol Dependence Scale; AUQ, Alcohol Urge Questionnaire; OCDS, Obsessive Compulsive Drinking Scale; BIS, Barratt Impulsivity Scale; SSRQ, Short Self-Regulation Questionnaire; BDI, Beck Depression Inventory; BAI, Beck Anxiety Inventory; MMSE, Folstein Mini-Mental State Examination.

Shown are group means ± standard deviations for AD and SD.

compared to SD, but its significance did not survive correction for multiple comparisons. There were no differences between AD and SD on the MMSE, BIS, the OCDS (including subscales), and the SSRQ. Four of 19 participants in the AD group were light drinkers according to the criteria used during recruitment/telephone screening (<15/25 drinks per week for women/men), while 1 of the 21 participants in the SD group was a heavy drinker according to these criteria (more than 14/24 drinks per week for women/men).

Effects of Cue Type, Regulation Instruction, and Group on Cue-Induced Craving

There was a significant main effect of regulation instruction, such that, collapsing across AD and SD groups as well as across alcohol and food cues, craving was significantly higher for NOW instructions than for LATER instructions, $F(1, 36) = 26.0$, $p < 0.0001$, $ES = 0.72$. There was also a

significant main effect of cue type, such that, collapsing across AD and SD groups as well as across NOW and LATER instructions, craving was significantly higher for food cues than for alcohol cues, $F(1, 36) = 5.51$, $p = 0.025$, $ES = 0.35$. There was no significant main effect of group, $F(1, 36) = 0.14$, $p = 0.71$, $ES = 0.09$. There was not a significant 3-way interaction between group, instruction, and cue type, $F(1, 36) = 0.71$, $p = 0.404$, and so a reduced model including only the significant 2-way interactions was run. The reduced model found a trend toward a significant interaction effect between instruction and group, $F(1, 36) = 3.55$, $p = 0.068$. After collapsing across cue type, a post hoc *t*-test showed that the significant effect of regulation instruction in SD ($t = 5.14$, $p < 0.0001$, $ES = 1.00$) was more than twice as large as the nonsignificant (after correcting for multiple comparisons) effect of regulation instruction in AD ($t = 2.29$, $p = 0.028$, $ES = 0.47$). There was a significant interaction effect between cue type and group on craving, $F(1, 36) = 7.81$, $p = 0.008$. After collapsing across regulation instructions, a post hoc *t*-test showed that craving was significantly higher for food than for alcohol in SD ($t = 3.60$, $p = 0.001$, $ES = 0.69$) but did not differ significantly between food and alcohol for AD ($t = 0.48$, $p = 0.64$, $ES = -0.10$) (Fig. 1).

Correlations Between Regulation Success and Baseline Measures

For SD, there was a significant and strong positive correlation between regulation success for ALCOHOL and regulation success for FOOD ($r = 0.86$, $p = 0.00001$). For AD, there was no significant correlation between regulation success for ALCOHOL and regulation success for FOOD ($r = 0.35$, $p = 0.14$) (Fig. 2). There was a trend toward a significant difference between these correlations ($t = 1.88$, $p = 0.069$) based on the regression testing the interaction of cue type regulation success by group. There were no significant correlations found for either AD or SD between regulation success for alcohol cues and any of the baseline self-report measures, including DPW, %HDD, SSRQ, ADS, OCDS, AUQ, and BIS (Table 3).

DISCUSSION

Here, we found support for the hypothesis that the cognitive regulation strategy of focusing on long-term negative consequences reduces self-reported cue-induced alcohol and food craving, that is, there was a significant main effect of regulation instruction, with craving during the LATER condition lower than during the NOW condition for both alcohol and food cues. While SD showed strong effects of this regulation strategy, AD showed relatively weak effects, with the difference in regulation ability between SD and AD, measured as the interaction between group and regulation instruction, trending toward statistical significance. This provides limited support for the hypothesis that AD are

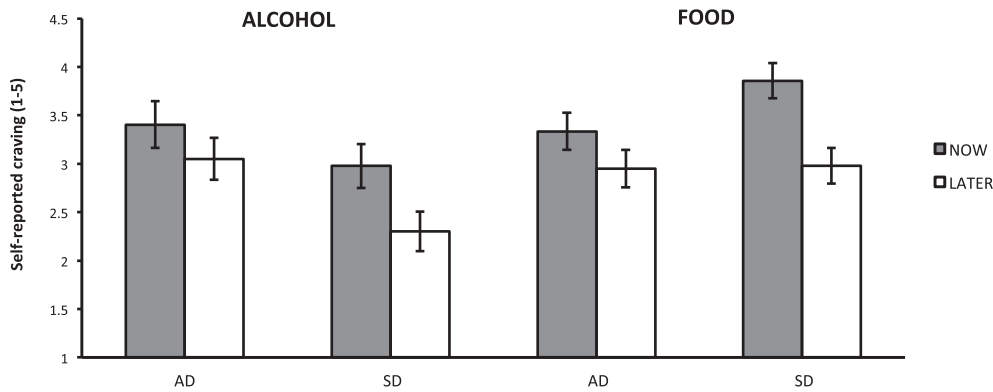


Fig. 1. Self-reported cravings elicited by alcohol and food cues, under instructions to think about long-term, negative consequences (NOW) or short-term, positive consequences (LATER).

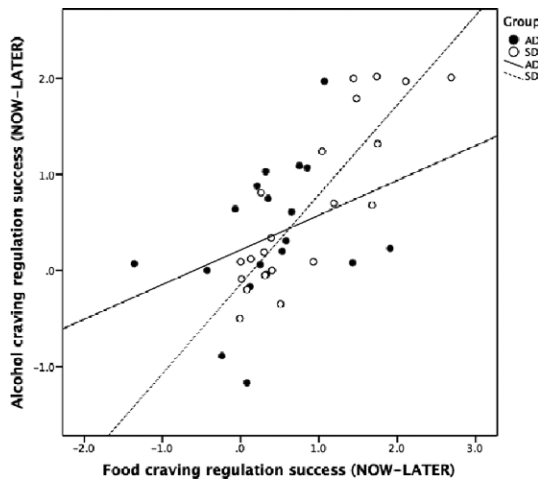


Fig. 2. Correlations between individual differences in regulation ability for cue-induced alcohol craving and cue-induced food craving, respectively. Regulation ability is operationalized as the difference between self-reported craving between NOW and LATER instructions, calculated for each cue-type, averaged for each subject.

Table 3. Correlations Between Ability to Regulate Cue-Induced Alcohol Craving (NOW-LATER) and Baseline Psychological Variables in Alcohol-Dependent (AD) and Social Drinkers (SD)

Variable	AD		SD	
	Correlation	<i>p</i> -Value	Correlation	<i>p</i> -Value
DPW	$r = -0.35$	0.14	$\rho = 0.03$	0.88
%HDD	$r = -0.01$	0.99	$\rho = -0.01$	0.96
SSRQ	$\rho = 0.31$	0.20	$\rho = -0.03$	0.90
ADS	$\rho = -0.23$	0.35	$\rho = -0.16$	0.50
OCDS	$\rho = 0.10$	0.68	$\rho = 0.17$	0.45
AUQ	$r = 0.31$	0.20	$\rho = -0.13$	0.59
BIS	$\rho = 0.23$	0.34	$\rho = -0.26$	0.26

DPW, drinks per week; %HDD, percent heavy-drinking days; SSRQ, Short Self-Regulation Questionnaire; ADS, Alcohol Dependence Scale; OCDS, Obsessive Compulsive Drinking Scale; AUQ, Alcohol Urge Questionnaire; BIS, Barratt Impulsivity Scale.

No significant correlations were found. Pearson's *r* reported for parametric data; Spearman's ρ reported for nonparametric data.

impaired in cognitively regulating craving, compared to SD. Contrary to our initial hypothesis, we found that these relative impairments in regulating craving in AD were not spe-

cific to alcohol cues, that is, there was not a significant 3-way interaction between regulation instruction, group, and cue type. Furthermore, we failed to find any correlations between individual differences in the ability to regulate cue-induced alcohol craving and any of the baseline self-report measures of alcohol dependence severity or self-regulation ability, in either AD or SD.

Overall, the results are consistent with the social learning theory that underlies CBT, which posits that alcohol-dependent individuals possess deficits in a variety of coping/regulation abilities, including the ability to self-regulate craving (Larimer et al., 1999), although our results show only a strong trend-level effect to support this model. With a larger sample size, it is likely that this effect would be significant and would support the existence of deficits in regulation of craving in AD versus SD. Similar studies in cigarette smokers using the same regulation of craving paradigm (Kober et al., 2010a) have shown that heavy smokers were no less able to cognitively regulate cue-induced cigarette craving than occasional smokers (“chippers”). Our results suggest, at a trend level, that craving regulation deficits may be more severe in alcohol dependence than in nicotine dependence.

Contrary to our initial hypothesis, the deficits in cognitive regulation of craving in AD compared to SD were not specific to alcohol cues, but generalized to food cues as well. Deficits in reward-related self-regulatory processes that have been previously been shown in AD, such as conflict monitoring (Field et al., 2007), response inhibition (Bjork et al., 2004; Lawrence et al., 2009), reward learning (Sjoerds et al., 2013), delayed discounting (Field et al., 2007), and reward-based decision making (Xiao et al., 2013), were mostly found using experimental tasks utilizing monetary rewards, not alcohol. This is consistent with AD being associated with a broad inability to regulate appetitive motivational states, as opposed to a specific inability to regulate alcohol-related motivational states. Another possibility is that, in the ROC task, AD may have a tendency to generate negative consequences that are less salient overall, leading to less apparent regulation ability for both alcohol and food craving.

In SD, the high degree of correlation between the ability to cognitively regulate cue-induced alcohol craving and cue-induced food craving, respectively, suggests that, in this group, some common factor underlies both forms of regulation. It is plausible that this common factor functions to regulate all appetitive emotional states, including food craving as well as craving for alcohol. In AD, we failed to find a significant correlation between the ability to regulate alcohol and food craving, respectively. This suggests that, in AD, regulation ability for food cues and alcohol cues, respectively, is determined by a different set of factors. We set out to uncover these factors by examining the correlations between the ability to cognitively regulate cue-induced alcohol craving and a number of self-report measures of heavy drinking, severity of alcohol dependence, trait impulsivity, self-reported self-regulation ability, baseline alcohol craving, and obsessive thoughts about alcohol, but found no significant relationships between regulation ability and any of these measures. The strongest relationship was found between cognitive regulation ability and heavy drinking (DPW), with a negative correlation of -0.35 ($p = 0.14$). With a larger sample size, it is possible that this would have been a significant negative correlation, which would suggest that heavier drinking is associated with greater impairments in cognitive regulation of cue-induced alcohol craving.

Interestingly, a number of these self-report measures that we collected at baseline (the BIS, SSRQ, OCDS) did not differ between AD and SD, even though these groups did differ in regulation ability in the current task. Therefore, it is not surprising that these self-report measures did not correlate with regulation ability. This could also explain the relatively low level of cue-induced craving in the AD group for the NOW condition; the AD patients in our sample may have attributed a relatively low level of incentive salience to alcohol cues, compared to a more severe population, for example. Furthermore, the absence of difference on the SSRQ (a self-report measure of general self-regulation ability) contrasts with our finding of impaired regulation of craving. This may be due to this particular self-report measure of self-regulation ability being less sensitive to deficits in AD, compared to the experimental measure that we utilized. Also, this task is a specific measure of regulation of craving, whereas the SSRQ addresses self-regulation more broadly, including domains that may not be impaired in AD.

This study possesses a number of limitations that may affect the interpretation of the results, as well as their generalizability and clinical applicability. The study was small, which reduced the power to detect some of the interaction effects, which were evident in large differences in regulation effect sizes between AD and SD that only trended toward significance. We included only non-treatment-seeking AD. This limits the ability to apply these results to treatment seekers, whose level of drinking may be higher and who are likely to have a higher motivation to regulate cravings at baseline. We also excluded participants with severe depression and anxiety and other substance use disorders, all of which may

limit generalizability, as these disorders are highly comorbid with alcohol dependence. As we did not measure participants' body mass index (BMI), we were unable to account for the potential confound of differences in regulation ability between AD and SD for food cues that were due to differences in BMI.

The ROC task used in this study has a number of limitations. While similar to a specific coping/regulation skill taught in CBT ("challenging and changing" thoughts about alcohol), the ROC task differs in that subjects were not instructed to have an explicit goal of reducing craving, as they are in CBT. This may limit the ability to use the results of this study to directly infer CBT mechanisms, as CBT teaches patients to have an explicit goal of regulating craving, in addition to providing them with strategies for going about this regulation. Additionally, the way the ROC task was designed did not allow us to determine whether the key cognitive factor that caused a reduction in cue-induced craving was thinking about negative consequences per se versus thinking about long-term consequences. This could be addressed by experiments that include conditions where subjects are instructed to think about long-term, *positive* consequences and short-term, negative consequences. Furthermore, we only addressed one specific cognitive coping/regulation skill, limiting the ability to make inferences about broad deficits in coping ability. Additionally, the experimental task was only 20 minutes long, which may have limited the sensitivity to detect differences between AD and SD.

CBT and related treatments are believed to change drinking behavior by improving cognitive regulation of craving and other coping skills (Larimer et al., 1999), although this has been difficult to prove (Morgenstern and Longabaugh, 2000). To examine whether coping skills acquisition is an active ingredient in the therapeutic mechanism of CBT, future studies may use the ROC task to track changes in regulation ability from pre- to post-CBT and to relate these to clinical outcomes of CBT. Furthermore, the ROC task could be adapted for functional neuroimaging experiments designed to uncover the neural systems that govern the regulation of cue-induced alcohol craving, how the functioning of these processes differs between AD and SD, and how treatments that are targeted at improving coping skills, such as CBT, can remediate the functioning of these neural systems.

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