Experimental and Clinical Psychopharmacology
2018, Vol. 26, No. 2, 138–146

1064-1297/18/$12.00 http://dx.doi.org/10.1037/pha0000177

Negative Mood-Induced Alcohol-Seeking Is Greater in Young Adults Who Report Depression Symptoms, Drinking to Cope, and Subjective Reactivity

Lee Hogarth and Lorna Hardy
University of Exeter

Amanda R. Mathew and Brian Hitsman
Northwestern University Feinberg School of Medicine

Acute negative mood powerfully motivates alcohol-seeking behavior, but it remains unclear whether sensitivity to this effect is greater in drinkers who report depression symptoms, drinking to cope, and subjective reactivity. To examine these questions, 128 young adult alcohol drinkers (ages 18–25) completed questionnaires of alcohol use disorder symptoms, depression symptoms, and drinking to cope with negative affect. Baseline alcohol choice was measured by preference to enlarge alcohol versus food thumbnail images in two-alternative forced-choice trials. Negative mood was then induced by depressive statements and music, before alcohol choice was tested. Subjective reactivity was indexed by increased sadness pre- to post-mood induction. Baseline alcohol choice correlated with alcohol dependence symptoms ($p = .001$), and drinking coping motives ($ps \leq .01$). Mood induction increased alcohol choice and subjective sadness overall ($ps < .001$). The mood-induced increase in alcohol choice was associated with depression symptoms ($p = .007$), drinking to cope ($ps \leq .03$), and subjective reactivity ($p = .007$). The relationship between mood-induced alcohol choice and drinking to cope remained significant after covarying for other drinking motives. Furthermore, the three predictors (depression, drinking to cope, and subjective reactivity) accounted for unique variance in mood-induced alcohol choice ($ps \geq .03$), and collectively accounted for 18% of the variance ($p < .001$). These findings validate the pictorial alcohol choice task as sensitive to the relative value of alcohol and acute negative mood. The findings also accord with the core prediction of negative reinforcement theory that sensitivity to the motivational impact of negative mood on alcohol-seeking behavior may be an important mechanism that links depression and alcohol dependence.

Public Health Significance
Negative mood is a key trigger for alcohol-seeking behavior, which may underpin vulnerability to alcohol dependence. The current study demonstrated, for the first time, that sensitivity to the motivational impact of negative mood on alcohol-seeking behavior is greater in young adults who report depression symptoms, drinking to cope, and subjective reactivity to negative events. Such sensitivity to negative mood-induced alcohol-seeking could increase vulnerability to alcohol dependence in these individuals.

Keywords: negative mood induction, depression, coping motives, mood reactivity, vulnerability to alcohol dependence

According to negative reinforcement theory, alcohol dependence, persistence, and relapse are driven by adverse withdrawal, cognitive, emotional, or psychiatric states, powerfully motivating alcohol use in order to mitigate those states (e.g., Crum et al., 2008; Hall et al., 2015; Mathew, Hogarth, Leventhal, Cook, & Hitsman, 2017). Perhaps the most direct evidence for negative reinforcement theory comes from experimental studies in which negative mood induction (including stress) is shown to motivate alcohol craving, choice, demand, consumption, and cognitive bias (Amlung & MacKillop, 2014; Field & Quigley, 2009; Rousseau, Irons, & Correia, 2011; Zack, Poulos, Fragopoulos, Woodford, & MacLeod, 2006). Negative reinforcement theory also predicts that

This article was published Online First February 1, 2018.

Lee Hogarth and Lorna Hardy, School of Psychology, University of Exeter; Amanda R. Mathew and Brian Hitsman, Department of Preventive Medicine, Northwestern University Feinberg School of Medicine.

The data and narrative interpretation contained within the article have not appeared before, either at a conference or at a meeting, posted on a Listserv, or shared on a website, including academic social networks.

This research was supported by an Economic and Social Research Council (ESRC) doctoral scholarship to Lorna Hardy and an Alcohol Research United Kingdom grant (RS17/03) to Lee Hogarth. The ESRC and Alcohol Research United Kingdom had no involvement other than financial support. All authors contributed in a significant way to the manuscript, and all authors have read and approved the final manuscript.

Correspondence concerning this article should be addressed to Lee Hogarth, School of Psychology, University of Exeter, Washington Singer Building, Perry Road, Exeter EX4 4QG, United Kingdom. E-mail: l.hogarth@exeter.ac.uk

individuals who are vulnerable to alcohol dependence should be more sensitive to negative affective triggers for alcohol-seeking behavior (Heilig, Egli, Crabbe, & Becker, 2010; Hussong, Jones, Stein, Baucom, & Boeding, 2011). Indirect support for this claim comes from the finding that sensitivity to negative mood-induced alcohol craving predicts relapse risk in alcoholics (Brady et al., 2006; Cooney, Litt, Morse, Bauer, & Gaupp, 1997; Higley et al., 2011; Sinha et al., 2011). However, it is not clear whether sensitivity to mood-induced alcohol-seeking is associated with other markers of alcohol dependence vulnerability, especially in young adult drinkers. To test this core prediction of negative reinforcement theory, the current study examined whether sensitivity to mood-induced alcohol-seeking was greater in young adult drinkers who report depression symptoms, drinking to cope, alcohol use disorder symptoms, and subjective reactivity to negative mood.

There is currently mixed evidence as to whether depression symptoms are associated with greater sensitivity to negative mood-induced alcohol-seeking behavior. Two studies have shown that depression symptom intensity had a numerically stronger correlation with alcohol craving measured after negative mood induction than after neutral induction, weakly suggesting that depression is associated with greater sensitivity to a mood-induced increase in craving (Cooney et al., 1997; Owens, Ray, & MacKillop, 2015). In contrast, we recently found that depression symptoms were not associated with greater sensitivity to mood-induced alcohol-seeking in a sample of 48 hazardous drinkers recruited from the community who completed a procedure very similar to the one used in the present study (Hardy & Hogarth, in press). However, this null association contrasts with two smoking studies. In the first study, we found that smokers with current major depressive disorder were more sensitive to a negative mood-induced increase in tobacco-seeking than smokers without major depression, and this sensitivity also increased linearly with depression symptom intensity across the entire sample (Hogarth, Mathew, & Hitsman, 2017). This finding corroborated an earlier study in which depression symptom intensity in heavy daily smokers was associated with sensitivity to the effect of negative mood induction on tobacco consumption (Fucito & Juliano, 2009). Given these mixed findings, the primary aim of the current study was to reexamine the relationship between depression symptoms and sensitivity to negative mood-induced alcohol-seeking in a large sample of young adult drinkers, testing a core prediction of negative reinforcement theory.

Self-reported drinking to cope has been consistently associated with sensitivity to mood-induced alcohol-seeking in young adult drinkers (Austin & Smith, 2008; Birch et al., 2004; Field & Powell, 2007; Field & Quigley, 2009; Grant, Stewart, & Birch, 2007; Rousseau et al., 2011; Woud, Becker, Rinck, & Salemink, 2015; Zack, Poulos, Fragopoulos, & MacLeod, 2003). In the present study, therefore, we expect that drinking to cope will be associated with greater sensitivity to mood-induced alcohol-seeking. The additional question, however, is whether this association is sufficiently specific to coping motives that it can survive when other drinking motives (enhancement, conformity, social pressure, and cued craving) are statistically controlled, as has been reported in two preliminary studies (Grant et al., 2007; Woud et al., 2015). This finding would indicate that the relationship between self-reported drinking to cope and sensitivity to negative mood-induced alcohol-seeking is not mediated by other drinking motives.

Existing studies are inconsistent as to whether severity of alcohol use disorder symptoms is associated with mood-induced alcohol-seeking. Although four studies have reported such an association (Randall & Cox, 2001; Sinha et al., 2009; Zack et al., 2003, 2006), seven studies have reported nonsignificant correlations (Austin & Smith, 2008; Cooney et al., 1997; Field & Powell, 2007; Field & Quigley, 2009; Hardy & Hogarth, in press; Woud et al., 2015; Zack, Toneatto, & MacLeod, 1999) and six other studies have not reported this correlation despite having the relevant data (Birch et al., 2004; Grant et al., 2007; McGrath, Jones, & Field, 2016; Owens et al., 2015; Potthast, Neuner, & Catani, 2015; Rousseau et al., 2011). Negative reinforcement theory predicts that alcohol dependence symptoms should be associated with mood-induced alcohol-seeking, if this is the underpinning mechanism. Therefore, the current study evaluated this association, to try and clarify the mixed findings.

There is also mixed evidence as to whether mood-induced alcohol-seeking is associated with subjective emotional reactivity to negative triggers. In relation to this association, there is weak evidence from three alcohol studies (Kelly, Masterman, & Young, 2011; Owens et al., 2015; Sinha et al., 2009), strong evidence from one smoking study (Hogarth et al., 2015), and nonsignificant correlations reported in two studies (Magrys & Olmstead, 2015; McGrath et al., 2016). Therefore, the current study evaluated the association between mood-induced alcohol-seeking and subjective mood reactivity, to address this mixed literature and the possible role of mood-regulation skills in alcohol dependence (Berking et al., 2011). Overall, if the current study found that sensitivity to mood-induced alcohol-seeking is associated with markers for alcohol dependence in young adults (depression symptoms, drinking to cope, alcohol use disorder severity, and subjective reactivity), these findings would provide initial support for the core prediction of negative reinforcement theory that sensitivity to mood-induced alcohol-seeking plays a role in vulnerability to alcohol dependence.

Method

Participants and Procedure

The study recruited 128 student drinkers (50% male) who reported drinking alcohol at least monthly. The study was approved by the University of Exeter psychology ethics committee and participants gave informed written consent. Participants completed questionnaires of alcohol use disorder, depression symptoms, and drinking motives. Baseline alcohol-seeking was measured by preference to select for enlargement alcohol- versus food-related thumbnail images in two-alternative forced-choice trials. This pictorial choice task was chosen because percentage drug choice increases with dependence severity and drug use frequency, suggesting that it indexes the relative value of the drug (Hardy & Hogarth, in press; Moeller et al., 2013; Moeller et al., 2009) and is reliably increased by mood induction (Hardy & Hogarth, in press; Hogarth et al., 2017). Negative mood was then induced by depressive statements and sad music, before alcohol-seeking was tested again in the same way. Subjective mood reactivity was indexed by the increase in sadness recorded pre- and post-mood induction. It was expected that mood induction would increase subjective sadness and alcohol-seeking overall. The question at stake was whether the mood-induced growth in alcohol-seeking would increase with de-

pression symptoms, drinking coping motives, alcohol use disorder severity, and subjective mood reactivity.

Questionnaires

The following questionnaires were completed. (1) The Alcohol Use Disorders Inventory Test (AUDIT; Babor, Higgins-Biddle, Saunders, & Monteiro, 2001) is scored on a scale of 1–40, where scores ≥8 indicate hazardous drinking. (2) Depression symptoms were recorded using Beck Depression Inventory II (BDI; Beck, Steer, Ball, & Ranieri, 1996), where scores of 0–13 = minimal, 14–19 = mild, 20–28 = moderate, and 29–63 = severe symptom intensity. (3) The Reasons for Drinking Questionnaire (RFDQ; Zywiak, Connors, Maisto, & Westerberg, 1996) negative coping subscale includes seven items which ask participants to assess how important different reasons for drinking are for their own consumption, including sadness, anger, frustration, anxiety, tension, illness, and relationship difficulties, measured on a 0–10 scale ranging from *not at all important* to *very important*. The RFDQ measured two other subscales: social pressure and cued craving. (4) The Drinking Motives Questionnaire—Revised (DMQ-R; Cooper, 1994) negative coping subscale contains five items which ask participants to assess how frequently their drinking is motived by each listed reason, including worries, depression/nervousness, bad mood, to build confidence, and to forget problems—rated on a 1–5 scale ranging from *almost never* to *almost always*. The DMQ-R measured three other subscales: social context, enhancement, and conformity.

Mood Induction Effect on Alcohol Choice

Baseline alcohol choice (see Figure 1). Instructions stated, "In this task you can choose to view images of alcohol and food using the left and right arrow keys. Press the space bar to begin." Each trial presented a pair of thumbnail images, one alcohol and one food related, randomly in the left and right positions, which remained until the left or right arrow key was chosen. This enlarged the chosen image, which remained alone on screen for 2 s. There were 32 baseline trials. The thumbnails were randomly sampled with replacement from a set of 28 alcohol images (including beer, wine, and spirits) and 28 food images (all typical U.K. dinners).

Mood induction. Participants first rated their current subjective mood on a scale of 1–9 ranging from *Happy* to *Sad* (baseline assessment). Instructions requested careful attention to statements

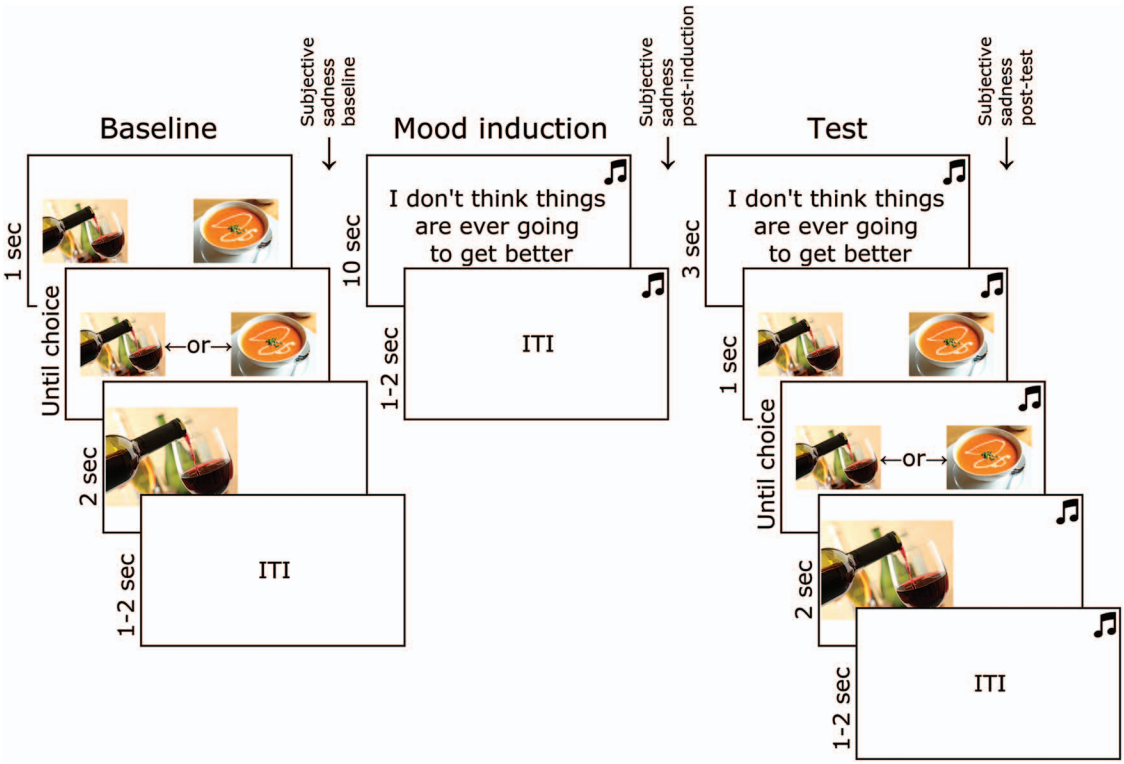

Figure 1. Procedure used to test the impact of negative mood induction on alcohol choice. At baseline, alcohol-seeking was measured by preference to select for enlargement alcohol versus food-related thumbnail images in two-alternative forced-choice trials. Negative mood was then induced by depressive statements and sad music (Samuel Barber's *Adagio for Strings*), before alcohol-seeking was tested again in the same way. Subjective reactivity was indexed by the increase in sadness pre- and post-mood induction. The key question was whether the increase in percentage choice of alcohol versus food images from baseline to test (mood-induced alcohol-seeking) would be associated with depression symptoms, drinking to cope, alcohol use disorder symptoms, and subjective reactivity. ITI = intertrial interval. See the online article for the color version of this figure.

then sad music (Samuel Barber's *Adagio for Strings*) began playing through headphones (Morrison & O'Connor, 2008). There followed 16 trials in which the 16 negative statements were presented once each, in random order, for 10 s. An example negative statement is "I do not think things are ever going to get better" (for the full list, see Hogarth et al., 2015). After these trials, participants rated their subjective mood again (postinduction assessment).

Test. Instructions stated, "You can now view alcohol and food pictures in the same way as before. Press the space bar to continue." There were 64 test trials each containing a negative statement randomly sampled from the set of 16 and presented for 3 s, before an alcohol or food choice was made in the same way as at baseline. The sad music continued to play throughout. After these 64 test trials, participants once again rated their subjective mood (posttest assessment).

Analytical Plan

Percentage choice of alcohol over food was calculated from baseline and test trials (>50% = preference for alcohol, <50% = preference for food). Analyses of variance (ANOVAs) first tested the difference in alcohol choice and subjective sadness between the baseline and test blocks. Separate mixed general linear models (GLMs) were then conducted with percentage alcohol choice as the dependent variable, the within-subjects variable block (baseline, test), and a continuous between-subjects variable in each model, either depression symptoms (BDI), RFDQ negative coping, DMQ-R negative coping, alcohol use disorder (AUDIT), or the increase in subjective sadness pre- and post-mood induction. A significant interaction in these GLMs would indicate that the change in alcohol choice from baseline to test (mood-induced alcohol-seeking) varied as a function of the continuous variable, revealing individual differences in sensitivity to mood-induced alcohol-seeking. A main effect of the continuous variable would indicate that there was a correlation between overall alcohol choice and the continuous variable.

Results

Participants

Of the 128 participants recruited, 13 were excluded for being outlying (>1.5 times the interquartile range) on either the dependent measures (percentage alcohol choice at baseline [$n = 3$], or test [$n = 0$]), or the continuous between-subjects predictor variables (depression symptoms [$n = 4$]; RFDQ negative coping [$n = 0$]; DMQ-R negative coping [$n = 0$]; alcohol use disorder [$n = 3$]; change in subjective sadness after mood induction [$n = 3$]). These exclusions were undertaken because GLMs can be adversely influenced by outliers (Draper & John, 1981). These exclusions did not change the key findings or conclusions of the study, and increase the reliability of the findings because they are cannot be attributed to outliers. The mean characteristics of the remaining 115 participants were as follows: age = 20.8 (*SD* = 1.3, range = 18–25), BDI = 4.6 (3.6, 0–16), RFDQ negative coping = 1.9 (1.7, 0–6.6), DMQ-R negative coping = 1.9 (.71, 1–3.6), and AUDIT = 9.11 (4.8, 1–21). AUDIT questions 1 to 3 were used to define the level of alcohol consumption in the sample. The sample means of 2.3, 1.5, and 1.6 for these questions respectively indicated that the sample, on average, drank somewhere between two to four times a month and two to three times a week, drank between three and six drinks in these drinking episodes, and had a binge drinking session (more than six drinks) approximately monthly. There were 58 males and 57 females.

Experimental Task

Subjective sadness. Subjective sadness measured postinduction ($M = 5.2$, $SEM = 0.17$) and posttest ($M = 5.35$, $SEM = 0.17$) were not significantly different, $F(1, 113) = 1.49$, $p = .22$, $\eta_p^2 = .013$, and were highly correlated ($r = .78$, $p < .001$), so were averaged for simplicity. Subjective sadness increased significantly from baseline ($M = 3.62$, $SEM = 0.14$) to the averaged postinduction/test score ($M = 5.3$, $SEM = 0.16$), $F(1, 113) = 122.68$, $p < .001$, $\eta_p^2 = .518$, indicating that the mood- induction procedure was effective in generating the intended change in mood.

Main effect of mood induction on alcohol-seeking. As shown in Figure 2A, percentage alcohol over food image choice increased significantly from baseline to test, $F(1, 113) = 29.55$, $p < .001$, $\eta_p^2 = .206$, demonstrating an effect of mood induction on alcohol-seeking in the sample as a whole. To determine whether the increase in alcohol choice from baseline to test was driven by mood-induction or time-related variables (e.g., habituation, sensitization, task disengagement), these two blocks were segmented into quarters. Percentage alcohol choice remained stable across quarters of the baseline block (22.3, 24.9, 24.0, 22.8, respectively) and then increased stepwise and remained stable across quarters of the test block (34.9, 34.3, 32.9, 31.4, respectively). ANOVA on these data with the variables block (baseline, test) and quarter (4) yielded a main effect of block, $F(1, 342) = 29.55$, $p < .001$, $\eta_p^2 = .206$, and no main effect of quarter, $F(3, 342) = 1.82$, $p = .14$, $\eta_p^2 = .016$, or Block × Quarter interaction, $F(3, 342) = 1.54$, $p = .21$, $\eta_p^2 = .013$. These findings suggest that the stepwise increase in alcohol choice from baseline to test was driven by the mood-induction procedure, rather than time-related variables.

Individual sensitivity to mood-induced alcohol-seeking. Table 1 shows the bivariate correlation matrix between the alcohol-seeking measures and questionnaire scales. The GLM involving the BDI shown in Figure 2B revealed a main effect of BDI, $F(1, 113) = 3.95$, $p < .05$, $\eta_p^2 = .034$, and a significant interaction between BDI and block (baseline, test), $F(1, 113) = 7.61$, $p = .007$, $\eta_p^2 = .063$. The GLM with the RFDQ negative coping subscale shown in Figure 2C revealed a significant main effect of RFDQ negative coping, $F(1, 113) = 12.88$, $p < .001$, $\eta_p^2 = .102$, and a significant interaction between RFDQ negative coping and block, $F(1, 113) = 4.68$, $p = .03$, $\eta_p^2 = .040$. Similarly, the GLM with the DMQ-R negative coping subscale shown in Figure 2D revealed a significant main effect of DMQ-R negative coping, $F(1, 113) = 22.62$, $p < .001$, $\eta_p^2 = .167$, and a significant interaction between DMQ-R negative coping and block, $F(1, 113) = 7.60$, $p = .007$, $\eta_p^2 = .063$. By contrast, the GLM with the AUDIT shown in Figure 2E showed a significant main effect of AUDIT, $F(1, 113) = 11.93$, $p = .001$, $\eta_p^2 = .095$, but no interaction between AUDIT and block, $F(1, 113) = 0.38$, $p = .54$, $\eta_p^2 = .003$. Finally, the GLM with mood reactivity (the increase in subjective sadness from baseline to the postinduction/test average) shown in Figure 2F revealed no main effect of mood reactivity, $F(1, 113) = 2.43$, $p = .12$, $\eta_p^2 = .021$, but an interaction between mood reactivity and block, $F(1, 113) = 7.55$, $p = .007$, $\eta_p^2 = .063$. In

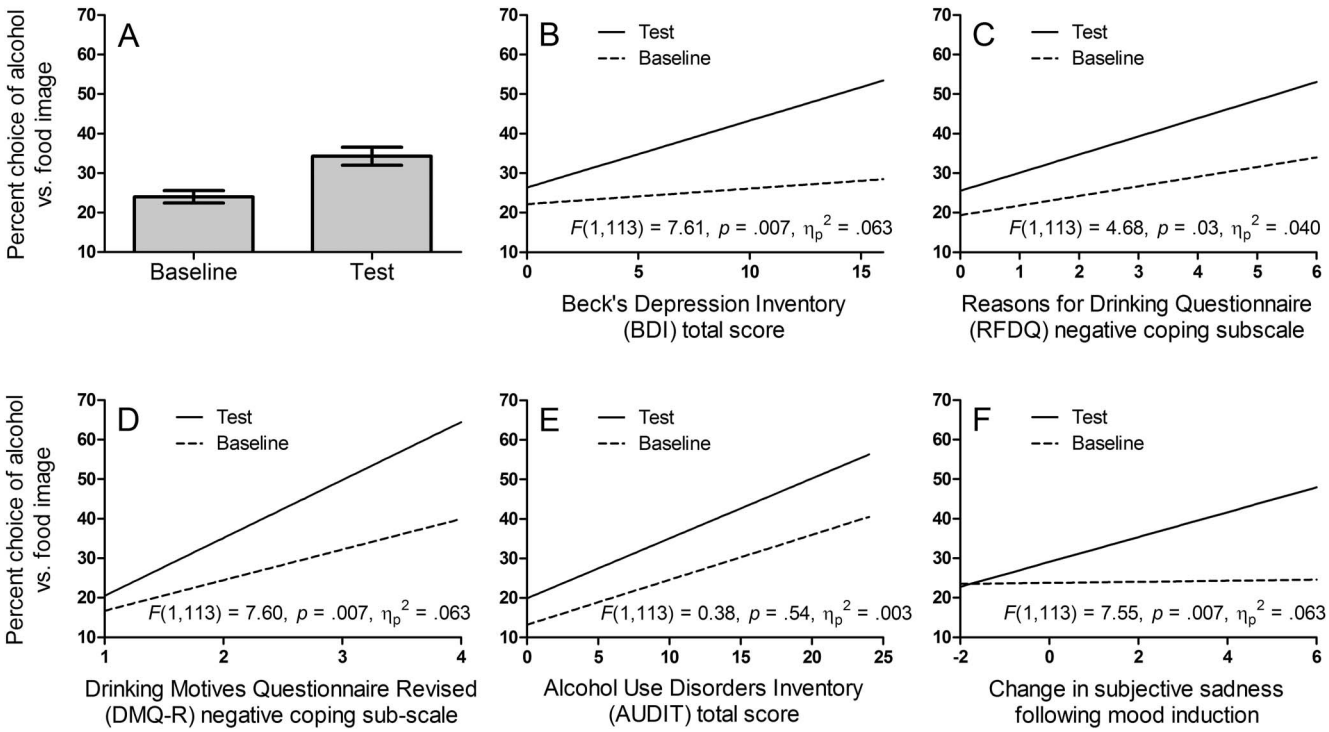

Figure 2. (A) Average percentage choice of alcohol versus food images in the baseline and test block (following negative mood induction). (B–F) Regression slopes relating percentage choice of alcohol versus food images at baseline and test with five continuous between-subjects variables: (B) Beck Depression Inventory (BDI) depression symptoms, (C) the Reasons for Drinking Questionnaire (RFDQ) negative coping subscale, (D) Drinking Motives Questionnaire—Revised (DMQ-R) negative coping subscale, (E) alcohol use disorder AUDIT scores, and (F) the change in subjective sadness from baseline to the postinduction/test average (subjective reactivity). The statistical insets report the interaction between the within-subjects variable block (baseline, test) and the continuous between-subjects variable. Block interacted significantly with depression symptoms (BDI), coping motives (RFDQ and DMQ-R), and subjective reactivity (but not alcohol use disorder), demonstrating greater sensitivity to mood-induced alcohol-seeking in these individuals.

summary, these results indicate that mood-induced alcohol-seeking is associated with BDI, RFDQ, and DMQ-R negative coping, and subjective mood reactivity, but not AUDIT.

Analyses of Other Drinking Motives

Further analyses were undertaken to explore the role of other RFDQ and DMQ-R subscales. GLMs following an identical structure (outlined in the analytical plan) indicated that all other RFDQ and DMR-R subscales showed a significant main effect, demonstrating an association with overall percentage alcohol choice: RFDQ social pressure, $F(1, 113) = 17.54$, $p < .001$, $\eta_p^2 = .134$; RFDQ cued craving, $F(1, 113) = 10.25$, $p = .002$, $\eta_p^2 = .083$; DMQ-R social context, $F(1, 113) = 11.54$, $p < .001$, $\eta_p^2 = .093$; DMQ-R enhancement, $F(1, 113) = 27.04$, $p < .001$, $\eta_p^2 = .193$, apart from DMQ-R conformity, $F(1, 113) = 1.38$, $p = .24$, $\eta_p^2 = .012$. More importantly, none of these RFDQ and DMQ-R subscales showed a significant interaction with block, indicating no evidence of an association with mood-induced alcohol-seeking: RFDQ social pressure, $F(1, 113) = 0.24$, $p = .62$ $\eta_p^2 = .002$; RFDQ cued craving, $F(1, 113) = 0.02$, $p = .88$, $\eta_p^2 = .000$; DMQ-R social context, $F(1, 113) = 0.72$, $p = .39$, $\eta_p^2 = .006$; DMQ-R enhancement, $F(1, 113) = 0.34$, $p = .56$ $\eta_p^2 = .003$; DMQ-R conformity, $F(1, 113) = 0.01$, $p = .94$, $\eta_p^2 = .000$. Finally, RFDQ negative coping continued to interact significantly with block (Figure 2C) when the other two RFDQ subscales were included in the GLM, $F(1, 111) = 9.68$, $p = .002$, $\eta_p^2 = .080$. Furthermore, the DMQ-R negative coping continued to interact significantly with block (Figure 2D) when the other three DMQ-R subscales were included in the GLM, $F(1, 110) = 10.43$, $p = .002$, $\eta_p^2 = .087$, demonstrating that mood-induced alcohol-seeking was selectively associated with negative coping motives.

Analysis of gender and age. Further analyses were undertaken to explore gender and age variables. An ANOVA incorporating gender (2) and block (2) revealed no main effect of gender, $F(1, 113) = 0.07$, $p = .79$, $\eta_p^2 = .001$, or interaction between gender and block, $F(1, 110) = 0.38$, $p = .54$, $\eta_p^2 = .003$. Similarly, a GLM incorporating age and block (2) revealed no effect of age, $F(1, 113) = 0.20$, $p = .66$, $\eta_p^2 = .002$, or interaction between age and block, $F(1, 113) = 0.02$, $p = .88$, $\eta_p^2 = .000$. These results indicate no evidence of relationships between mood-induced alcohol-seeking and gender or age.

Multiple regression: predicting mood-induced alcohol-seeking. A multiple-regression model was undertaken to determine the pro-

Table 1
Correlation Matrix Between Alcohol-Seeking Measures and Questionnaires

Measure	% alcohol choice test	Mood-induced alcohol-seeking	BDI	RFDQ negative coping	DMQ-R negative coping	AUDIT	Subjective reactivity
% alcohol choice baseline	$r = .61$	$r = -.09$	$r = .06$	$r = .24$	$r = .31$	$r = .31$	$r = .02$
	$p < .001$	$p = .31$	$p = .54$	**$p = .01$**	**$p = .001$**	**$p = .001$**	$p = .87$
% alcohol choice test		$r = .73$	$r = .24$	$r = .32$	$r = .41$	$r = .26$	$r = .21$
		$p < .001$	**$p = .01$**	**$p < .001$**	**$p < .001$**	**$p = .005$**	**$p = .03$**
Mood-induced alcohol-seeking			$r = .25$	$r = .20$	$r = .25$	$r = .06$	$r = .25$
			$p = .007$	**$p = .03$**	**$p = .007$**	$p = .538$	**$p = .007$**
BDI				$r = .35$	$r = .37$	$r = .23$	$r = -.10$
				$p < .001$	**$p < .001$**	**$p = .01$**	$p = .29$
RFDQ negative coping					$r = .71$	$r = .40$	**$r = -.20$**
					$p < .001$	**$p < .001$**	**$p = .03$**
DMQ-R negative coping						$r = .54$	$r = -.13$
						$p < .001$	$p = .16$
AUDIT							$r = .01$
							$p = .89$

Note. Mood-induced alcohol-seeking was the difference in percentage alcohol choice between baseline and test conditions (positive values indicate a bigger mood-induction effect). AUDIT = Alcohol Use Disorders Inventory; RFDQ = Reasons for Drinking Questionnaire; DMQ-R = Drinking Motives Questionnaire—Revised; BDI = Beck's Depression Inventory. Boldface text highlights the significant correlations.

portion of variance in mood-induced alcohol-seeking accounted for by the predictors, as well as the independence of the predictors. The RFDQ and DMQ-R negative coping scores were highly correlated ($r = .71$, $p < .001$), and so were converted to z scores to normalize their distribution, and averaged to create a single index. The dependent variable was mood-induced alcohol-seeking, that is, the increase in alcohol choice from baseline to test. The three predictor variables entered into the model were the BDI, the combined RFDQ/DMQ-R negative coping score, and mood reactivity (i.e., the increase in subjective sadness from baseline to the postinduction/test average score). These predictors explained a significant proportion (18%) of variance in mood-induced alcohol-seeking, $F(3, 111) = 7.97$, $p < .001$, $R^2 = .18$. Furthermore, all three predictor variables accounted for unique variance: BDI, $\beta = .20$, $t(114) = 2.17$, $p = .03$; combined negative coping, $\beta = .21$, $t(114) = 2.26$, $p = .03$; and subjective mood reactivity, $\beta = .31$, $t(114) = 3.54$, $p = .001$.

Discussion

The most novel and theoretically pertinent finding of the study was that depression symptoms were associated with greater sensitivity to negative mood-induced alcohol-seeking. As noted in the introduction, two previous alcohol studies provided weak evidence for this association (Cooney et al., 1997; Owens et al., 2015), and one study failed to detect this association in a sample of 48 hazardous community drinkers who completed the same task as the present (Hardy & Hogarth, in press), perhaps due to low power or narrow variance in depression scores. In contrast, a correlation between depression and sensitivity to negative mood-induced tobacco-seeking was found in a small sample of smokers preselected to have high and low depression symptoms (Hogarth et al., 2017, corroborating Fucito & Juliano, 2009). Therefore, the current study is the first to demonstrate that depression is associated with sensitivity to mood-induced alcohol-seeking, just as depression is associated with mood-induced tobacco-seeking, consistent with a core prediction of negative reinforcement theory. Given the relatively young sample, this finding provides evidence for a negative reinforcement mechanism that could drive vulnerability to future alcohol dependence in individuals reporting depression symptoms.

The association between coping motives and mood-induced alcohol-seeking has been demonstrated in a number of previous studies, in young adult drinkers (Austin & Smith, 2008; Birch et al., 2004; Field & Powell, 2007; Field & Quigley, 2009; Grant et al., 2007; Rousseau et al., 2011; Woud et al., 2015; Zack et al., 2003) and alcoholic men (Cooney et al., 1997). Although we failed to find this association with hazardous community drinkers (Hardy & Hogarth, in press), perhaps due to low power or restricted variance in drinking-to-cope scores. The unique contribution of the current study was to demonstrate that the relationship between drinking to cope and mood-induced alcohol-seeking could not be attributed to other drinking motives, supporting earlier preliminary findings (Grant et al., 2007; Woud et al., 2015). In addition, we found that drinking to cope and depression symptoms accounted for unique variance in the mood-induced alcohol-seeking, suggesting no (cross-sectional) mediation effects, perhaps contradicting the view that coping motives are the proximal determinants of behavior (Cooper, Frone, Russell, & Mudar, 1995). However, the true status of any mediation pathways among depression symptoms, drinking to cope, and mood-induced alcohol-seeking can only be resolved by a more highly powered study.

The relationship between subjective reactivity and mood-induced alcohol-seeking supports prior weak evidence for this relationship from three alcohol studies (Kelly et al., 2011; Owens et al., 2015; Sinha et al., 2009), and strong evidence from one smoking study (Hogarth et al., 2015), and contradicts two null findings (Magrys & Olmstead, 2015; McGrath et al., 2016). Despite subjective reactivity being associated with mood-induced alcohol choice, there is a question as to whether this measure is a clinically meaningful marker, because it did not correlate positively with depression symptoms, coping motives, or alcohol use disorder severity. Given this, it seems unlikely that subjective reactivity reflects the sort of mood-regulation skills that are thought to confer risk for alcohol dependence (Berking et al., 2011).

The most troubling finding, from the perspective of negative reinforcement theory, was that alcohol use disorder severity indexed by the AUDIT was not associated with sensitivity to negative mood-induced alcohol-seeking. This null association is actually backed by the weight of published evidence, with seven studies reporting a similar null association (Austin & Smith, 2008; Cooney et al., 1997; Field & Powell, 2007; Field & Quigley, 2009; Hardy & Hogarth, in press; Woud et al., 2015; Zack et al., 1999), and only four studies reporting a significant association (Randall & Cox, 2001; Sinha et al., 2009; Zack et al., 2003, 2006). From these data, one could reject the core tenet of negative reinforcement theory, and conclude that negative mood-induced alcohol-seeking does not underpin alcohol dependence. Alternatively, one could dismiss these null associations on the assumption that questionnaires of alcohol dependence (such as the AUDIT) are not optimized to identify young adult drinkers who are most at risk of developing alcohol dependence in the future, because they largely assess drinking frequency, rather than perceived loss of control over drinking (Pilkonis et al., 2016). Indeed, within the current sample, the mean variance of AUDIT items reflecting drinking frequency (Questions 1–3) was .57, substantially larger than the (constrained) mean variance of .19 for items reflecting alcohol problems (Questions 4–10). It is possible that drinking frequency in young adults might be driven by various factors including friendship networks (Kuntsche et al., 2014), whereas perceived loss of control over drinking might be more closely associated with sensitivity to mood-induced alcohol-seeking. A better test of negative reinforcement theory, therefore, would be to examine whether negative mood-induced alcohol-seeking is associated with a questionnaire that specifically indexes perceived loss of control over drinking in young adults, rather than drinking frequency (Pilkonis et al., 2016).

Baseline alcohol choice appeared to index individual differences in the relative value of alcohol. Baseline alcohol choice correlated with alcohol use disorder (AUDIT) scores and drinking to cope with negative affect as indexed by two questionnaires, corroborating a previous study with hazardous community drinkers (Hardy & Hogarth, in press). Two related cocaine studies using a pictorial cocaine choice procedure have found that cocaine choice is associated with cocaine use frequency (Moeller et al., 2013; Moeller et al., 2009). Furthermore, similar choice procedures, in which smokers choose between points exchangeable for tobacco versus food, have demonstrated that tobacco choice correlates with cigarettes smoked per day, smoking days per week, craving, and dependence (Chase, MacKillop, & Hogarth, 2013; Hogarth, 2012; Hogarth & Chase, 2011, 2012). These findings suggest that percentage drug choice in these procedures indexes the relative value of the drug, which underpins consumption frequency and dependence severity. We might therefore have greater confidence that the effect of negative mood induction on alcohol choice models the motivational processes driving alcohol consumption and dependence in the natural environment.

It is noteworthy that depression symptoms and negative coping motives were not associated with greater subjective reactivity to mood induction. The null association between depression symptoms and subjective mood reactivity is consistent with our previous study (Hardy & Hogarth, in press) and substantial literature (Bylsma, Morris, & Rottenberg, 2008; Falkenberg, Kohn, Schoepker, & Habel, 2012). The implication is that increased sensitivity to mood-induced alcohol-seeking in young adult drinkers who report depression symptoms and coping motives is not mediated by heightened subjective reactivity to negative mood triggers. Rather, we propose that negative mood induction more effectively motivated alcohol-seeking in individuals with high depression/coping scores because these individuals have had more experience of the greater reward value of alcohol in the negative mood state, which allows the negative mood state to more effectively promote goal-directed alcohol-seeking, through incentive learning (Hogarth et al., 2015; Hutcheson, Everitt, Robbins, & Dickinson, 2001; Mathew et al., 2017).

One limitation of the study was that the negative mood induction condition was not compared against a control condition (as has been done in other studies; Hogarth et al., 2015). The current design was selected to maximize the ability to detect individual differences in sensitivity to negative mood-induced alcohol-seeking by running all participants in that condition. The weakness, however, is that the increase in alcohol choice from baseline to test could be interpreted as being driven by mood-induction or by time-related variables such as sensitization or habituation to stimuli, or task disengagement. Additional analyses, however, revealed that alcohol choice increased as a step-function immediately following negative mood induction, and did not change significantly across quarters within each block. This suggests that the increase in alcohol choice at test was driven by the mood-induction procedure rather than time-related variables.

To conclude, this study found that sensitivity to negative mood-induced alcohol-seeking was greater in young adults who reported depression symptoms, drinking to cope, and subjective reactivity to mood induction. These findings accord with the core prediction of negative reinforcement theory that certain vulnerable individuals are more sensitive to the motivational impact of negative states on alcohol-seeking behavior. This sensitivity arguably underpins the risk of alcohol dependence in vulnerable individuals, but longitudinal and causal studies are needed to confirm this prediction.

References

Amlung, M., & MacKillop, J. (2014). Understanding the effects of stress and alcohol cues on motivation for alcohol via behavioral economics. *Alcoholism: Clinical and Experimental Research, 38,* 1780–1789. http://dx.doi.org/10.1111/acer.12423

Austin, J. L., & Smith, J. E. (2008). Drinking for negative reinforcement: The semantic priming of alcohol concepts. *Addictive Behaviors, 33,* 1572–1580. http://dx.doi.org/10.1016/j.addbeh.2008.07.016

Babor, T. F., Higgins-Biddle, J. C., Saunders, J. B., & Monteiro, M. G. (2001). *AUDIT: The alcohol use disorders identification test guidelines for use in primary care* (2nd ed.). Geneva, Switzerland: World Health Organization. Retrieved from http://apps.who.int/iris/bitstream/10665/67205/1/WHO_MSD_MSB_01.6a.pdf

Beck, A. T., Steer, R. A., Ball, R., & Ranieri, W. (1996). Comparison of Beck Depression Inventories—IA and —II in psychiatric outpatients. *Journal of Personality Assessment, 67,* 588–597. http://dx.doi.org/10.1207/s15327752jpa6703_13

Berking, M., Margraf, M., Ebert, D., Wupperman, P., Hofmann, S. G., & Junghanns, K. (2011). Deficits in emotion-regulation skills predict alcohol use during and after cognitive–behavioral therapy for alcohol dependence. *Journal of Consulting and Clinical Psychology, 79,* 307–318. http://dx.doi.org/10.1037/a0023421

Birch, C. D., Stewart, S. H., Wall, A. M., McKee, S. A., Eisnor, S. J., & Theakston, J. A. (2004). Mood-induced increases in alcohol expectancy

strength in internally motivated drinkers. *Psychology of Addictive Behaviors, 18,* 231–238. http://dx.doi.org/10.1037/0893-164X.18.3.231

Brady, K. T., Back, S. E., Waldrop, A. E., McRae, A. L., Anton, R. F., Upadhyaya, H. P., . . . Randall, P. K. (2006). Cold pressor task reactivity: Predictors of alcohol use among alcohol-dependent individuals with and without comorbid posttraumatic stress disorder. *Alcoholism: Clinical and Experimental Research, 30,* 938–946. http://dx.doi.org/10.1111/j.1530-0277.2006.00097.x

Bylsma, L. M., Morris, B. H., & Rottenberg, J. (2008). A meta-analysis of emotional reactivity in major depressive disorder. *Clinical Psychology Review, 28,* 676–691. http://dx.doi.org/10.1016/j.cpr.2007.10.001

Chase, H. W., Mackillop, J., & Hogarth, L. (2013). Isolating behavioural economic indices of demand in relation to nicotine dependence. *Psychopharmacology, 226,* 371–380. http://dx.doi.org/10.1007/s00213-012-2911-x

Cooney, N. L., Litt, M. D., Morse, P. A., Bauer, L. O., & Gaupp, L. (1997). Alcohol cue reactivity, negative-mood reactivity, and relapse in treated alcoholic men. *Journal of Abnormal Psychology, 106,* 243–250. http://dx.doi.org/10.1037/0021-843X.106.2.243

Cooper, M. L. (1994). Motivations for alcohol use among adolescents: Development and validation of a four-factor model. *Psychological Assessment, 6,* 117–128. http://dx.doi.org/10.1037/1040-3590.6.2.117

Cooper, M. L., Frone, M. R., Russell, M., & Mudar, P. (1995). Drinking to regulate positive and negative emotions: A motivational model of alcohol use. *Journal of Personality and Social Psychology, 69,* 990–1005. http://dx.doi.org/10.1037/0022-3514.69.5.990

Crum, R. M., Green, K. M., Storr, C. L., Chan, Y. F., Ialongo, N., Stuart, E. A., & Anthony, J. C. (2008). Depressed mood in childhood and subsequent alcohol use through adolescence and young adulthood. *Archives of General Psychiatry, 65,* 702–712. http://dx.doi.org/10.1001/archpsyc.65.6.702

Draper, N. R., & John, J. A. (1981). Influential observations and outliers in regression. *Technometrics, 23,* 21–26. http://dx.doi.org/10.1080/00401706.1981.10486232

Falkenberg, I., Kohn, N., Schoepker, R., & Habel, U. (2012). Mood induction in depressive patients: A comparative multidimensional approach. *PLoS ONE, 7*(1), e30016. http://dx.doi.org/10.1371/journal.pone.0030016

Field, M., & Powell, H. (2007). Stress increases attentional bias for alcohol cues in social drinkers who drink to cope. *Alcohol and Alcoholism, 42,* 560–566. http://dx.doi.org/10.1093/alcalc/agm064

Field, M., & Quigley, M. (2009). Mild stress increases attentional bias in social drinkers who drink to cope: A replication and extension. *Experimental and Clinical Psychopharmacology, 17,* 312–319. http://dx.doi.org/10.1037/a0017090

Fucito, L. M., & Juliano, L. M. (2009). Depression moderates smoking behavior in response to a sad mood induction. *Psychology of Addictive Behaviors, 23,* 546–551. http://dx.doi.org/10.1037/a0016529

Grant, V. V., Stewart, S. H., & Birch, C. D. (2007). Impact of positive and anxious mood on implicit alcohol-related cognitions in internally motivated undergraduate drinkers. *Addictive Behaviors, 32,* 2226–2237. http://dx.doi.org/10.1016/j.addbeh.2007.02.012

Hall, F. S., Der-Avakian, A., Gould, T. J., Markou, A., Shoaib, M., & Young, J. W. (2015). Negative affective states and cognitive impairments in nicotine dependence. *Neuroscience and Biobehavioral Reviews, 58,* 168–185. http://dx.doi.org/10.1016/j.neubiorev.2015.06.004

Hardy, L., & Hogarth, L. (in press). A novel concurrent pictorial choice model of mood-induced relapse in hazardous drinkers. *Experimental and Clinical Psychopharmacology*.

Heilig, M., Egli, M., Crabbe, J. C., & Becker, H. C. (2010). Acute withdrawal, protracted abstinence and negative affect in alcoholism: Are they linked? *Addiction Biology, 15,* 169–184. http://dx.doi.org/10.1111/j.1369-1600.2009.00194.x

Higley, A. E., Crane, N. A., Spadoni, A. D., Quello, S. B., Goodell, V., & Mason, B. J. (2011). Craving in response to stress induction in a human laboratory paradigm predicts treatment outcome in alcohol-dependent individuals. *Psychopharmacology, 218,* 121–129. http://dx.doi.org/10.1007/s00213-011-2355-8

Hogarth, L. (2012). Goal-directed and transfer-cue-elicited drug-seeking are dissociated by pharmacotherapy: Evidence for independent additive controllers. *Journal of Experimental Psychology: Animal Behavior Processes, 38,* 266–278. http://dx.doi.org/10.1037/a0028914

Hogarth, L., & Chase, H. W. (2011). Parallel goal-directed and habitual control of human drug-seeking: Implications for dependence vulnerability. *Journal of Experimental Psychology: Animal Behavior Processes, 37,* 261–276. http://dx.doi.org/10.1037/a0022913

Hogarth, L., & Chase, H. W. (2012). Evaluating psychological markers for human nicotine dependence: Tobacco choice, extinction, and Pavlovian-to-instrumental transfer. *Experimental and Clinical Psychopharmacology, 20,* 213–224. http://dx.doi.org/10.1037/a0027203

Hogarth, L., He, Z., Chase, H. W., Wills, A. J., Troisi, J., II, Leventhal, A. M., . . . Hitsman, B. (2015). Negative mood reverses devaluation of goal-directed drug-seeking favouring an incentive learning account of drug dependence. *Psychopharmacology, 232,* 3235–3247. http://dx.doi.org/10.1007/s00213-015-3977-z

Hogarth, L., Mathew, A. R., & Hitsman, B. (2017). Current major depression is associated with greater sensitivity to the motivational effect of both negative mood induction and abstinence on tobacco-seeking behavior. *Drug and Alcohol Dependence, 176,* 1–6. http://dx.doi.org/10.1016/j.drugalcdep.2017.02.009

Hussong, A. M., Jones, D. J., Stein, G. L., Baucom, D. H., & Boeding, S. (2011). An internalizing pathway to alcohol use and disorder. *Psychology of Addictive Behaviors, 25,* 390–404. http://dx.doi.org/10.1037/a0024519

Hutcheson, D. M., Everitt, B. J., Robbins, T. W., & Dickinson, A. (2001). The role of withdrawal in heroin addiction: Enhances reward or promotes avoidance? *Nature Neuroscience, 4,* 943–947. http://dx.doi.org/10.1038/nn0901-943

Kelly, A. B., Masterman, P. W., & Young, R. M. (2011). Negative mood, implicit alcohol-related memory, and alcohol use in young adults: The moderating effect of alcohol expectancy. *Addictive Behaviors, 36,* 148–151. http://dx.doi.org/10.1016/j.addbeh.2010.08.025

Kuntsche, E., Gabhainn, S. N., Roberts, C., Windlin, B., Vieno, A., Bendtsen, P., . . . Wicki, M. (2014). Drinking motives and links to alcohol use in 13 European countries. *Journal of Studies on Alcohol and Drugs, 75,* 428–437. http://dx.doi.org/10.15288/jsad.2014.75.428

Magrys, S. A., & Olmstead, M. C. (2015). Acute stress increases voluntary consumption of alcohol in undergraduates. *Alcohol and Alcoholism, 50,* 213–218. http://dx.doi.org/10.1093/alcalc/agu101

Mathew, A. R., Hogarth, L., Leventhal, A. M., Cook, J. W., & Hitsman, B. (2017). Cigarette smoking and depression comorbidity: Systematic review and proposed theoretical model. *Addiction, 112,* 401–412. http://dx.doi.org/10.1111/add.13604

McGrath, E., Jones, A., & Field, M. (2016). Acute stress increases ad-libitum alcohol consumption in heavy drinkers, but not through impaired inhibitory control. *Psychopharmacology, 233,* 1227–1234. http://dx.doi.org/10.1007/s00213-016-4205-1

Moeller, S. J., Beebe-Wang, N., Woicik, P. A., Konova, A. B., Maloney, T., & Goldstein, R. Z. (2013). Choice to view cocaine images predicts concurrent and prospective drug use in cocaine addiction. *Drug and Alcohol Dependence, 130,* 178–185. http://dx.doi.org/10.1016/j.drugalcdep.2012.11.001

Moeller, S. J., Maloney, T., Parvaz, M. A., Dunning, J. P., Alia-Klein, N., Woicik, P. A., . . . Goldstein, R. Z. (2009). Enhanced choice for viewing cocaine pictures in cocaine addiction. *Biological Psychiatry, 66,* 169–176. http://dx.doi.org/10.1016/j.biopsych.2009.02.015

Morrison, R., & O'Connor, R. C. (2008). The role of rumination, attentional biases and stress in psychological distress. *British Journal of Psychology, 99,* 191–209. http://dx.doi.org/10.1348/000712607X216080

Owens, M. M., Ray, L. A., & MacKillop, J. (2015). Behavioral economic analysis of stress effects on acute motivation for alcohol. *Journal of the Experimental Analysis of Behavior, 103,* 77–86. http://dx.doi.org/10.1002/jeab.114

Pilkonis, P. A., Yu, L., Dodds, N. E., Johnston, K. L., Lawrence, S. M., & Daley, D. C. (2016). Validation of the alcohol use item banks from the Patient-Reported Outcomes Measurement Information System (PROMIS). *Drug and Alcohol Dependence, 161,* 316–322. http://dx.doi.org/10.1016/j.drugalcdep.2016.02.014

Potthast, N., Neuner, F., & Catani, C. (2015). When abuse primes addiction—Automatic activation of alcohol concepts by child maltreatment related cues in emotionally abused alcoholics. *Addictive Behaviors, 48,* 62–70. http://dx.doi.org/10.1016/j.addbeh.2015.05.004

Randall, D. M., & Cox, W. M. (2001). Experimental mood inductions in persons at high and low risk for alcohol problems. *American Journal of Drug and Alcohol Abuse, 27,* 183–187. http://dx.doi.org/10.1081/ADA-100103126

Rousseau, G. S., Irons, J. G., & Correia, C. J. (2011). The reinforcing value of alcohol in a drinking to cope paradigm. *Drug and Alcohol Dependence, 118,* 1–4. http://dx.doi.org/10.1016/j.drugalcdep.2011.02.010

Sinha, R., Fox, H. C., Hong, K. A., Bergquist, K., Bhagwagar, Z., & Siedlarz, K. M. (2009). Enhanced negative emotion and alcohol craving, and altered physiological responses following stress and cue exposure in alcohol dependent individuals. *Neuropsychopharmacology, 34,* 1198–1208. http://dx.doi.org/10.1038/npp.2008.78

Sinha, R., Fox, H. C., Hong, K. I., Hansen, J., Tuit, K., & Kreek, M. J. (2011). Effects of adrenal sensitivity, stress- and cue-induced craving, and anxiety on subsequent alcohol relapse and treatment outcomes. *Archives of General Psychiatry, 68,* 942–952. http://dx.doi.org/10.1001/archgenpsychiatry.2011.49

Woud, M. L., Becker, E. S., Rinck, M., & Salemink, E. (2015). The relationship between drinking motives and alcohol-related interpretation biases. *Journal of Behavior Therapy and Experimental Psychiatry, 47,* 102–110. http://dx.doi.org/10.1016/j.jbtep.2014.11.012

Zack, M., Poulos, C. X., Fragopoulos, F., & MacLeod, C. M. (2003). Effects of negative and positive mood phrases on priming of alcohol words in young drinkers with high and low anxiety sensitivity. *Experimental and Clinical Psychopharmacology, 11,* 176–185. http://dx.doi.org/10.1037/1064-1297.11.2.176

Zack, M., Poulos, C. X., Fragopoulos, F., Woodford, T. M., & MacLeod, C. M. (2006). Negative affect words prime beer consumption in young drinkers. *Addictive Behaviors, 31,* 169–173. http://dx.doi.org/10.1016/j.addbeh.2005.04.016

Zack, M., Toneatto, T., & MacLeod, C. M. (1999). Implicit activation of alcohol concepts by negative affective cues distinguishes between problem drinkers with high and low psychiatric distress. *Journal of Abnormal Psychology, 108,* 518–531. http://dx.doi.org/10.1037/0021-843X.108.3.518

Zywiak, W. H., Connors, G. J., Maisto, S. A., & Westerberg, V. S. (1996). Relapse research and the Reasons for Drinking Questionnaire: A factor analysis of Marlatt's relapse taxonomy. *Addiction, 91,* 121–130. http://dx.doi.org/10.1046/j.1360-0443.91.12s1.2.x

Received October 5, 2017
Revision received November 24, 2017
Accepted November 25, 2017 ■