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Effects of alcohol, rumination, and gender on the time course of negative affect

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ABSTRACT

This study modelled associations between gender, ruminative cognitive style, alcohol use, and the time course of negative affect over the course of 43,111 random assessments in the natural environment. Participants ($N = 263$) completed 49 days of experience sampling over 1.3 years. The data indicated that rumination at baseline was positively associated with alcohol dependence symptoms at baseline as well as higher negative affect over the course of the study. Consistent with negative reinforcement models, drinking served to decrease the persistence of negative affect from moment to moment. However, this ameliorative effect of drinking was evident only among women, suggesting an increased risk for negative reinforcement driven drinking behaviour. In addition, rumination appeared to counteract the desired effects of alcohol on mood among women. This suggests that women who ruminate more may be motivated to consume larger amounts of alcohol to achieve the desired effects. Overall, the results indicate that ruminative cognitive style and the persistence of negative affect from moment to moment may reflect an individual vulnerability for the development of alcohol use disorder especially among women.

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Dysregulated negative affect is not only a hallmark feature of mood disorders, but has been linked to alcohol and other substance use disorders as well (Cheetham, Allen, Yucel, & Lubman, 2010; Koob, 2013). The use of alcohol for managing emotional states is a prominent motivation underlying drinking behaviour with particular relevance for the development of alcohol use disorder (AUD; Cox & Klinger, 1990; McCarthy, Curtin, Piper, & Baker, 2010; Piasecki et al., 2014; Simons, Gaher, Correia, Hansen, & Christopher, 2005). Nonetheless, the majority of persons do not rely on alcohol to regulate their mood and empirical findings linking negative affect and alcohol use suggest that there are complex relationships that vary across time, person, and situation (Greeley & Oei, 1999; Sher & Grekin, 2007; Simons, Wills, & Neal, 2014). Ruminative cognitive style is an individual difference variable that may increase risk of maladaptive use of alcohol in an attempt to attenuate the persistence of

negative affect. Incorporating the time course of negative affective states and degree of baseline rumination into explanatory models can advance research on associations between negative affect and drinking.

The duration of negative affective experiences varies considerably between individuals, with some having fleeting episodes, while others have episodes that can last months or even years (Nolen-Hoeksema, 1991). Whereas discrete negative affective states are important for adaptive functioning (Kashdan, Feldman-Barrett, & McKnight, 2015), the tendency for negative affect to persist is an important risk factor for psychological disorders, especially depressive disorders (Kuppens, Allen, & Sheeber, 2010; Kuppens et al., 2012; Sadikaj, Russell, Moskowitz, & Paris, 2010). The persistence of affective states reflects a strong autocorrelation in affect from moment-to-moment, a process termed emotional inertia in the literature (Fairbairn & Sayette, 2013; Green, Hillis, & Suls,

1998; Kuppens et al., 2010). In respect to negative affect, this suggests an inward focus on sources of turmoil and a lack of engagement in the social world. The person is not responding to the inherently varied emotionally relevant stimuli they encounter. The attention allocation model (Steele & Josephs, 1988) posits that the effect of alcohol on mood stems in part from its ability to disrupt focus on internal states and attend to the present moment (Fairbairn & Sayette, 2013). Thus, where ruminative cognitive styles are thought to increase emotional inertia and associated negative affect (Koval, Kuppens, Allen, & Sheeber, 2012; Moberly & Watkins, 2008a, 2008b), alcohol may serve to free one from inertia, and improve mood.

Negative reinforcement drinking

Negative reinforcement is inherently a within-person process. As such, experience sampling provides an optimal approach to examining this process in the natural environment. Daily-process research on associations between negative affect and alcohol consumption has predominantly structured the research question to examine whether negative affect serves as a stimulus for increased drinking (e.g. Armeli, Todd, Conner, & Tennen, 2008; Hussong, 2007; Park, Armeli, & Tennen, 2004; Simons, Dvorak, Batien, & Wray, 2010; Simons, Gaher, Oliver, Bush, & Palmer, 2005; Simons et al., 2014). Fewer daily-process studies have tested whether drinking is associated with subsequent reductions in negative affect (Armeli et al., 2003; Jahng et al., 2011; Swendsen et al., 2000). Armeli et al. (2003) and Swendsen et al. (2000) found that alcohol consumption was concurrently associated with reduced negative affect and Armeli et al. (2003) found that alcohol consumption was prospectively associated with reduced negative affect later in the evening. Jahng et al. (2011) examine prospective effects of alcohol use on mood controlling for drinking both during and after the target mood assessment. They did not find evidence of the effects of alcohol on reductions in negative affect. However, their results are difficult to interpret, as the specific effect of drinking on the association between affect assessments across time was not tested.

Rumination

Response styles theory (RST; Nolen-Hoeksema, 1991) proposes that rumination is a risk factor for the

onset and maintenance of depression and persistent dysphoria. In RST, rumination consists of repetitively thinking about the causes, consequences, and symptoms of one's negative affect. RST further postulates that this tendency to ruminate in response to negative mood is thought to be a stable individual difference factor that contributes to the continuity of negative affect observed in mood and anxiety disorders (Nolen-Hoeksema, 2004). Consistent with this position, experimental studies show that inducing rumination leads to subsequent increases in, and the prolonging of, both depressed and anxious moods (Blagden & Craske, 1996; McLaughlin, Borkovec, & Sibrava, 2007; Nolen-Hoeksema, 2000; Nolen-Hoeksema, Morrow, & Fredrickson, 1993). Prospective studies have found that rumination predicts the onset of major depressive episodes (Just & Alloy, 1997; Nolen-Hoeksema, 2000; Spasojević & Alloy, 2001) and is associated with the severity and chronicity of depressive episodes (Alloy & Robinson, 2003; Kuehner & Weber, 1999; Nolen-Hoeksema, 2000). More broadly, rumination is a transdiagnostic risk factor associated with a variety of disorders (Nolen-Hoeksema & Watkins, 2011). For example, the tendency to ruminate is related to symptoms of generalized anxiety (Fresco, Frankel, Mennin, Turk, & Heimberg, 2002; McEvoy, Watson, Watkins, & Nathan, 2013), posttraumatic stress (Ehring, Frank, & Ehlers, 2008; Mayou, Ehlers, & Bryant, 2002), and social anxiety (Brozovich & Heimberg, 2008; Chen, Rapee, & Abbott, 2013; Mellings & Alden, 2000). The current consensus is that rumination leads to increases in negative affect that, in turn, foster further repetitive negative cognitions which propagate greater, more persistent negative affect in a self-perpetuating positive feedback loop (Ciesla & Roberts, 2007; Lyubomirsky & Nolen-Hoeksema, 1995; Nolen-Hoeksema, 1991; Pasyugina, Koval, De Leersnyder, Mesquita, & Kuppens, 2015).

RST proposes that rumination should lead to greater continuity in negative affect from moment-to-moment (Nolen-Hoeksema, 1991, 2004). There has been increased interest in recent years in testing this central tenet of the theory in the natural environment (Brans, Koval, Verduyn, Lim, & Kuppens, 2013; Koval, Pe, Meers, & Kuppens, 2013; Koval et al., 2012; Moberly & Watkins, 2008a, 2008b; Pasyugina et al., 2015; Takano & Tanno, 2011). These experience sampling studies largely operationalized rumination as a time-varying process and demonstrated within-person associations between rumination and persistence of negative affective states. They thus shed

important light on the hypothesized within-person process of rumination on the time course of negative affect. Despite the strengths of this approach, emotion and cognition are closely entwined and it remains possible that the persistence of negative arousal is “pulling for” rumination rather than vice versa. Indeed, supplemental analyses of one experience sampling study supported this contention in that negative affect predicted rumination at the within-person level (Pasyugina et al., 2015). However, Koval et al. (2012) did test the effects of trait rumination measured at baseline on the persistence of negative affect (i.e. emotional inertia) in a brief experience sampling study. Consistent with hypotheses, rumination at baseline predicted marginally stronger autoregressive effects of negative affect and significantly stronger persistence in the specific emotions of dysphoria and sadness.

There are multiple ways in which rumination may contribute to risk for AUD. At the most basic level, rumination may increase risk due to the increased persistence of negative affect, which, in turn, reinforces alcohol use. In addition, the ability of alcohol to disrupt ruminative cognitive style may suggest that alcohol has stronger effects on emotional inertia for those who ruminate more. Alternatively, given that the effects of alcohol and rumination oppose each other, rumination may serve to attenuate the effects of alcohol on emotional inertia, potentially resulting in higher levels of consumption to obtain the desired effect. The current study addresses this gap in the literature.

Gender effects

Women are at increased risk for depressive and anxiety disorders and decreased risk for AUDs relative to men (Eaton et al., 2012). There are numerous theoretical models for gender effects on risk for these disorders (Eaton et al., 2012; Nolen-Hoeksema, 2001, 2012). Of relevance to the current study, increased risk for depression seen among women has been tied to the tendency to ruminate about negative emotion and events. Women are more likely than men to ruminate, as assessed by both self-report and laboratory observation (Butler & Nolen-Hoeksema, 1994; Nolen-Hoeksema, Larson, & Grayson, 1999). Furthermore, rumination has been shown to mediate the relationship between female gender and increased negative affect (Butler & Nolen-Hoeksema, 1994; Jose & Brown, 2008; Nolen-Hoeksema, 2012) and there is some evidence that the association between

rumination and depression may be stronger for women (Jose & Brown, 2008).

Given the role of negative reinforcement in the development of AUD (Baker, Piper, McCarthy, Majeskie, & Fiore, 2004; McCarthy et al., 2010), and the observed increased risk of AUD among men (Eaton et al., 2012), one possibility is that men may experience greater beneficial effects of drinking on negative affect and drink more to cope than women (Nolen-Hoeksema, 2012). However, research has been inconsistent, with results of several studies suggesting that women report drinking to cope more than men (Hussong, 2007; LaBrie, Ehret, Hummer, & Prenovost, 2012; Rice & Van Arsdale, 2010), exhibit stronger associations between coping motives and drinking (Lehavot, Stappenbeck, Luterek, Kaysen, & Simpson, 2014), and exhibit stronger associations between negative affect and relapse to alcohol use (Annis, Sklar, & Moser, 1998; Zywiak, Connors, Maisto, & Westerberg, 1996; Zywiak et al., 2006). Still others report no gender differences in associations between negative affect and alcohol use (Simons, Gaher, Oliver et al., 2005; Walitzer & Dearing, 2006; Witkiewitz & Villarroya, 2009). Reasons for the disparities in the literature likely stem from a number of sources including sample differences in respect to age (Kuntsche, Knibbe, Gmel, & Engels, 2006), socio-cultural factors (Bloomfield, Gmel, & Wilsnack, 2006), and severity of mood or alcohol related problems (Foster et al., 2014; Nolen-Hoeksema & Hilt, 2006). In addition, much of the research does not clearly delineate the effects of gender on the within-person association between alcohol and negative affect or the effects of alcohol on emotional inertia. As discussed previously, laboratory research indicates that alcohol may improve mood by reducing emotional inertia (Fairbairn & Sayette, 2013), but whether this effect varies as a function of gender is unknown.

The current study

Understanding of psychopathology can be advanced by research on the time course of negative affective states (Ebner-Priemer, Eid, Kleindienst, Stabenow, & Trull, 2009; Fairbairn & Sayette, 2013; Kuppens et al., 2012; Simons et al., 2014). The experience of negative affect is a dynamic process within the individual and both excessive variability (i.e. lability; Jahng et al., 2011; Simons et al., 2014) and excessive stability (i.e. inertia; Fairbairn & Sayette, 2013; Kuppens et al., 2012)

appear to be characteristics of different forms of pathology. Ruminative cognitive styles are thought to promote the persistence of negative affective states across time and increase risk for depressive disorders (Moberly & Watkins, 2008a; Nolen-Hoeksema, 1991; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). In contrast, effects of alcohol on disrupting emotional inertia (Fairbairn & Sayette, 2013) and alleviating negative affect (Piasecki et al., 2014; Sher, Bartholow, Peuser, Erickson, & Wood, 2007) negatively reinforce alcohol use and potentially contribute to the development of an AUD (Baker et al., 2004; McCarthy et al., 2010). In the current study, we seek to advance understanding of these issues by testing between-person effects of trait rumination and gender, and within-person effects of alcohol consumption, on the persistence of negative affect across random *in situ* assessments (i.e. the strength of autocorrelation across time lags). Furthermore, we test whether emotional inertia is positively associated with negative affectivity. Consistent with negative reinforcement models of drinking, it was hypothesized that drinking would reduce associations between negative affect across successive time points. In line with RST, it was hypothesized that ruminative cognitive style assessed at baseline would predict a greater persistence of negative affect, operationalized as a stronger association between negative affect at time $t-1$ and negative affect at time t . Given the elevated risk of women for depressive and anxiety disorders we test whether women exhibit a stronger persistence of negative affect after accounting for the hypothesized effect of rumination and whether the effect of rumination on the persistence of negative affect is stronger for women relative to men. In addition, we test whether the effect of drinking on the persistence of negative affect is stronger for men or women. That is, is there evidence of a stronger negative reinforcement process for men or women? Given the inconsistencies in the literature we do not make a directional hypothesis for this effect. Finally, we test associations between rumination and alcohol dependence symptoms at baseline, and whether the within-person effects of drinking on negative affect vary as a function of rumination and gender.

Method

Participants

Participants were 274 undergraduate college students at 2 Midwest universities. The sample ranged from 18

to 27 years of age ($M = 19.88$, $SD = 1.37$) and was 56% female and was 93% White, 1% African American, 1% Asian, 1% Native American, 1% Native Hawaiian/Pacific Islander, and 3% other race or did not respond; 3% of the sample were Hispanic. The sample demographic characteristics are comparable with the university populations, which have approximately 60% women and 6–14% ethnic minorities. Recruitment was conducted through e-mail notices and advertisements in local media. Three other articles have been published from portions of this dataset as part of a larger study investigating factors associated with heavy drinking (Simons, Wills, Emery, & Marks, 2015; Simons, Wills, Emery, & Spelman, 2015; Simons et al., 2014).

Procedure

Undergraduates who drank at least moderately (i.e. ≥ 12 standard drinks per week for women and ≥ 16 standard drinks per week for men; Sanchez-Craig, Wilkinson, & Davila, 1995) were invited to participate in the experience sampling method (ESM) study. Invited participants provided informed consent for the study, completed a set of baseline questionnaires, and were then trained in the use of the handheld computer. Palm handhelds were programmed with Purdue Momentary Assessment Tool (PMAT) software (Weiss, Beal, Lucy, & MacDermid, 2004), modified by Joel Swendsen and CNRS, France. The programme generated prompts for participants to complete brief ~ 2 -minute assessments at random times within 2-hour blocks between 10:00 am and 12:00 midnight. Random assessment items inquired about participants' behaviour for the past 30 minutes. Participants were asked to answer questionnaires during waking hours and could turn the machine off when they would be sleeping or otherwise did not wish to be disturbed (e.g. taking an exam). The validity of the proposed sampling design is supported by previous research (Armeli et al., 2003; Simons et al., 2010; Simons, Gaher, Oliver et al., 2005; Swendsen et al., 2000). For a further description of the study's procedure, see Simons et al. (2014). The study was a burst design in which participants carried the handheld computer for 1–2 weeks during 2 periods over 3 semesters, resulting in 6 measurement bursts totalling 49 days of data. Individuals received \$20 for the baseline assessment and then received payments contingent on response rates during each burst (up to \$25/week). Participants completing all six bursts

received a \$50 bonus. All procedures were approved by the IRBs at the two universities.

Experience sampling measures

Negative affect

Situational negative affect (i.e. negative affect in the previous 30 minutes) was assessed by items from subscales of the PANAS-X (Watson & Clark, 1994) and Larsen and Diener's affect circumplex model (Larsen & Diener, 1992). Cronbach's alphas were calculated for one signal per person on one day in each burst. We report the mean of the six estimates. Negative affect ($\alpha = .80$) was assessed by nine items representing three dimensions: sadness (three items: sad, blue, downhearted), anxiety (three items: nervous, jittery, anxious), and hostility (three items: angry, hostile, irritable). Items were rated on 7-point scales ranging from 1 = *not at all* to 7 = *extremely*. Previous research supports the internal consistency and criterion validity of these and comparable affect scales assessed by experience sampling (Armeli et al., 2003; Csikszentmihalyi & Larson, 1992; Simons, Gaher, Oliver et al., 2005). This measure was reported up to eight times per day.

Alcohol consumption

Alcohol consumption was assessed by *in situ* assessments of drinks. Participants reported the number of drinks they consumed over the past 30 minutes on an 8-point scale (0–7 or more drinks). Definitions of standard drinks were provided during the palmtop training. In the current model, drinking was a dichotomous variable signifying the presence or absence of drinking at the signal. This measure was reported up to eight times per day.

Baseline measures

Rumination

Dispositional rumination tendency was assessed at baseline with a six-item composite inventory on dealing with sadness and anger, included in the Sadness and Anger Management Scale (Shipman, Zeman, Penza, & Champion, 2000; Zeman, Shipman, & Penza-Clyve, 2001). Three items assessed sadness rumination. Example item, "When people do something to make me sad, I don't forget about it." Three items assessed anger rumination. Example item "I often find myself thinking about things that have made me angry." These were scored on 5-point scale

ranging from "not at all true" to "Very true". Previous research shows that this adapted inventory has adequate internal consistency and convergent validity with other measures of poor emotional control (Wills, Pokhrel, Morehouse, & Fenster, 2011; Wills et al., 2013; Wills, Walker, Mendoza, & AINETTE, 2006). Cronbach's $\alpha = .83$ in the current sample.

Alcohol dependence symptoms

The Alcohol Dependence Scale (ADS; Skinner & Allen, 1982; Skinner & Horn, 1984) was used to assess symptoms of alcohol dependence syndrome. The scale contains 25 items assessing dyscontrolled drinking ($\alpha = .80$), and exhibits good convergent validity with other indicators of AUD (Doyle & Donovan, 2009). This scale was used to test whether rumination is associated with symptoms of AUD.

Results

Attrition and response analysis

Of the 274 participants enrolled in the study, 11 were dropped because of poor compliance with the protocol, resulting in an analytic sample of 263. The participants in the analysis sample completed 79% of the random prompts, which is in line with data from other experience sampling studies (cf. Piasecki et al., 2011; Shiffman, 2009; Stone & Shiffman, 2002). An average of 268.98 (SD = 162.26; median = 376, range 7–562) days elapsed between participants' first and last assessments. On average, the 263 participants provided daily data on 74% of the targeted 49 assessment days. The mean number of assessment days per participant was 36.36 (SD = 13.91). The number of assessment days was not correlated with gender or rumination, or mean negative affect during the study (r 's < .03). The number of assessment days was inversely associated with the proportion of signals (i.e. random prompts) drinking was reported ($r = -.20, p < .01$). The average time between assessments was 1.69 hours (SD = 0.80). We set the maximum allowable time gap to be 4 hours, so all successive assessments are within a day.

Descriptive statistics

Table 1 reports the means and between-person correlations. Men drank on a higher proportion of assessments and reported less rumination and negative affect relative to women. Rumination score at baseline

Table 1. Descriptive statistics.

Variable	Source	Mean (SD) or percent	Skew	Kurtosis	1	2	3	4
1. Gender	Baseline	44% Men			-			
2. Rumination	Baseline	2.69 (0.98)	0.33	2.34	-.17**			
3. ADS	Baseline	12.74 (5.69)	0.57	3.07	-.06	.26***		
3. Negative affect	Signal	1.48 (0.71)	2.37	10.42	-.14**	.31***	.19**	
4. Drinking	Signal	7% of Signals			.21***	-.05	.16*	.16*

Notes: 263 persons, 43,111 signals. Signals refer to the *in situ* random assessments. Correlations are between the person means. ADS: Alcohol Dependence Scale. Gender is coded 1 = men, 0 = women.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

and mean negative affect reported across *in situ* assessments were moderately correlated. Negative affect, but not rumination, was positively correlated with the proportion of random assessments (i.e. signals) when the person reported drinking. Consistent with expectation, rumination was moderately positively correlated with scores on the ADS at baseline.

Multilevel analysis

The core of the multilevel model was an autoregression of negative affect (i.e. negative affect at time t regressed on negative affect at time $t-1$). The autoregression of negative affect across successive assessments operationalizes the persistence of negative affect through time, otherwise referred to as emotional inertia (Koval et al., 2012). Level 1 (i.e. signal) predictors test whether, for example, drinking at $t-1$ predicts the subsequent level of negative affect at time t over and above the effect of previous negative affect (i.e. negative affect (NA) $t-1$). The interaction between drinking $_{t-1}$ and NA $_{t-1}$ tests whether drinking reduces the expected association between NA $_{t-1}$ and NA $_t$. That is, does drinking disrupt the persistence of negative affect across time resulting in reduced distress? The cross-level interactions between baseline rumination or gender and NA $_{t-1}$ test whether the persistence of negative affect from $t-1$ to t varies as a function of rumination or gender, respectively. The three-way cross-level interaction between drinking $_{t-1}$, NA $_{t-1}$, and rumination then tests whether the effect of drinking on the persistence of negative affect varies as a function of ruminative cognitive styles. Similarly, the interaction between drinking $_{t-1}$, NA $_{t-1}$, and gender tests if the effect of drinking on the persistence of negative affect varies as a function of gender. The interaction between gender, rumination, and NA $_{t-1}$ tests whether the effect of ruminative cognitive style on the persistence

of negative affect varies as a function of gender. Finally, the four-way interaction between gender, rumination, drinking $_{t-1}$, and NA $_{t-1}$ can be conceptualized as whether men and women differ in the extent to which effects of drinking on the persistence of negative affect vary as a function of ruminative cognitive style. Given that the effects of drinking or ruminative cognitive styles on the persistence of negative affective states may vary depending on the severity of negative arousal, we include a quadratic effect in the model and corresponding interaction terms discussed previously. In addition, day of the week (at the daily level) and elapsed days (at the person and daily levels) were included in the model as covariates. We tested for a potential quadratic effect of elapsed time, but it was not significant and hence not included.

The model included 43,111 observations. The data had a four-level structure with signals (Level 1) nested within days (Level 2), nested within measurement burst (Level 3), and nested within person (Level 4). We modelled random intercepts at the person, burst, and day level to allow for variation in mean levels of negative affect across time and person. In addition, we tested for potential random slopes. This resulted in modelling a random slope for lagged negative affect and elapsed date at the person level and a random lagged negative affect slope at the burst level. Drinking and negative affect were measured at the signal level. Drinking was a dichotomous indicator, the presence or absence of drinking at time $t-1$. Continuous level 1 variables (i.e. negative affect, elapsed date) were centred at the person mean and continuous level 2 variables (e.g. rumination, time in the study [subject mean of elapsed date], subject mean drinking [proportion of drinking signals across assessments]) were centred at the grand mean. Dichotomous variables were not centred. To maintain focus on within-person effects of Level 1 drinking variable, we include the subject mean at Level 2 (Enders & Tofighi, 2007). Residuals followed an AR 1

autoregressive structure. All analyses were conducted using Stata 13 (StataCorp, 2013). The initial model included a five-way $NA_{t-1} \times NA_{t-1} \times drinking_{t-1} \times rumination \times gender$ interaction. This was not significant ($p = .852$) and hence was dropped and the model re-estimated. Examining the higher order interactions revealed that the $NA_{t-1} \times NA_{t-1} \times drinking_{t-1} \times rumination$ was also not significant ($p = .665$) and hence was dropped. This resulted in a more parsimonious model including three significant four-way interactions (and their respective lower order components). Hence, the model contains the following fixed effects:

At Level 1 (signal)

$$\begin{aligned} \text{Negative affect (NA)}_{tdbi} &= \beta_0 + \beta_1(NA_{t-1dbi}) \\ &+ \beta_2(NA_{t-1dbi} * NA_{t-1dbi}) + \beta_3(drinking_{t-1dbi}) \\ &+ \beta_4(drinking_{t-1dbi} * NA_{t-1dbi}) \\ &+ \beta_5(drinking_{t-1dbi} * NA_{t-1dbi} * NA_{t-1dbi})+ \end{aligned}$$

Level 2 (day)

$$\begin{aligned} &\beta_6(\text{elapsed date}_{dbi}) + \beta_7(\text{Monday}_{dbi}) + \beta_8(\text{Tuesday}_{dbi}) \\ &+ \beta_9(\text{Wednesday}_{dbi}) + \beta_{10}(\text{Thursday}_{dbi}) \\ &+ \beta_{11}(\text{Friday}_{dbi}) + \beta_{12}(\text{Saturday}_{dbi})+ \end{aligned}$$

Level 3 (burst) No level 3 fixed effects

Level 4 (person)

$$\begin{aligned} &\beta_{13}(\text{gender}_i) + \beta_{14}(\text{rumination}_i) \\ &+ \beta_{15}(\text{gender}_i * \text{rumination}_i) \\ &+ \beta_{16}(\text{subject mean elapsed date}_i) \\ &+ \beta_{17}(\text{subject mean drinking}_i)+ \end{aligned}$$

Cross-level interactions

$$\begin{aligned} &\beta_{18}(\text{gender}_i * NA_{t-1d}\beta_i) \\ &+ \beta_{19}(\text{gender}_i * NA_{t-1dbi} * NA_{t-1dbi}) \\ &+ \beta_{20}(\text{gender}_i * drinking_{t-1dbi}) \\ &+ \beta_{21}(\text{gender}_i * NA_{t-1dbi} * drinking_{t-1dbi}) \\ &+ \beta_{22}(\text{gender}_i * NA_{t-1dbi} * NA_{t-1dbi} * drinking_{t-1dbi}) \\ &+ \beta_{23}(\text{rumination}_i * NA_{t-1dbi}) \\ &+ \beta_{24}(\text{rumination}_i * NA_{t-1dbi} * NA_{t-1dbi}) \\ &+ \beta_{25}(\text{rumination}_i * drinking_{t-1dbi}) \\ &+ \beta_{26}(\text{rumination}_i * NA_{t-1dbi} * drinking_{t-1dbi}) \\ &+ \beta_{27}(\text{rumination}_i * \text{gender}_i * NA_{t-1dbi}) \\ &+ \beta_{28}(\text{rumination}_i * \text{gender}_i * NA_{t-1dbi} * NA_{t-1dbi}) \\ &+ \beta_{29}(\text{rumination}_i * \text{gender}_i * drinking_{t-1dbi}) \\ &+ \beta_{30}(\text{rumination}_i * \text{gender}_i \\ &* NA_{t-1dbi} * drinking_{t-1dbi}) \end{aligned}$$

In addition to the fixed effects, there are several random effects estimated. The model has a random residual component res_{tdbi} at Level 1. The negative affect_t intercept (β_0) has random variation at Level 2 (day, $u0_{dbi}$), Level 3 (burst, $r0_{bi}$), and Level 4 (person, $e0_i$). The negative affect_{t-1} slope (β_1) has random variation at Level 3 (burst, $r1_{bi}$), and Level 4 (person, $e1_i$). Finally, the elapsed date slope (β_5) has random variation at Level 4 (person, $e5_i$).

Results are presented in Table 2. As expected, the rumination score from baseline was associated with higher mean levels of negative affect over the course of the study; and there was a clear effect of negative affect on subsequent negative affect assessments (i.e. autocorrelation). There was a significant quadratic NA_{t-1} effect, signifying a decelerating

Table 2. Multilevel autoregression analysis predicting negative affect at time t , fixed effect.

Variable	B	SEB	z	p
Between-person effects (Level 4)				
Gender	-0.10	0.05	-2.10	.036
Rumination	0.16	0.03	5.31	<.001
Gender \times Rumination	-0.09	0.05	-1.93	.053
Subject mean elapsed date	0.05	0.03	1.67	.095
Subject mean drinking	0.97	0.30	3.21	.001
Within-person effects				
Burst level (Level 3, no fixed effects)				
Day level (Level 2)				
Elapsed date	-0.01	0.00	-3.69	<.001
Signal level (Level 1)				
NA_{t-1}	0.43	0.01	29.93	<.001
$NA_{t-1} \times NA_{t-1}$	-0.02	0.01	-2.79	.005
$drinking_{t-1}$	-0.04	0.02	-2.02	.044
$drinking_{t-1} \times NA_{t-1}$	-0.03	0.03	-0.79	.432
$drinking_{t-1} \times NA_{t-1} \times NA_{t-1}$	-0.07	0.01	-4.98	<.001
Cross-level interactions				
$NA_{t-1} \times \text{gender}$	-0.04	0.02	-1.78	.075
$NA_{t-1} \times \text{rumination}$	0.02	0.01	1.50	.135
$NA_{t-1} \times \text{rumination} \times \text{gender}$	-0.04	0.02	-2.02	.044
$NA_{t-1} \times NA_{t-1} \times \text{gender}$	-0.02	0.01	-2.31	.021
$NA_{t-1} \times NA_{t-1} \times \text{rumination}$	-0.01	0.01	-0.99	.323
$NA_{t-1} \times NA_{t-1} \times \text{rumination} \times \text{gender}$	0.03	0.01	3.29	.001
$drinking_{t-1} \times \text{gender}$	0.04	0.02	1.63	.104
$drinking_{t-1} \times \text{rumination}$	0.00	0.02	0.18	.854
$drinking_{t-1} \times \text{gender} \times \text{rumination}$	0.01	0.02	0.32	.749
$drinking_{t-1} \times NA_{t-1} \times \text{rumination}$	0.04	0.02	1.49	.136
$drinking_{t-1} \times NA_{t-1} \times \text{gender}$	0.02	0.05	0.41	.685
$drinking_{t-1} \times NA_{t-1} \times NA_{t-1} \times \text{gender}$	0.07	0.02	3.82	<.001
$drinking_{t-1} \times NA_{t-1} \times \text{gender} \times \text{rumination}$	-0.07	0.04	-2.06	.039

Notes: 263 persons, 43,111 signals. Six orthogonal day-of-week indicators were included, Friday and Saturday were associated with reduced negative affect relative to Sunday. Gender is coded 1 = men, 0 = Women. Drinking is coded 1 = Drinking, 0 = not drinking. Women and not drinking are the base categories. NA = negative affect.

curve indicating that periods of heightened negative affect tended to start to return to baseline. The association between level of negative affect and emotional inertia is evident in the person-level random effects (see Table 3), where the correlation between the random NA_{t-1} slope and the NA_t intercept was $r = .49$, 95% CI [.23, .68]. This indicates that individuals with higher mean levels of negative affect exhibit stronger associations between negative affect across successive time points (i.e. a stronger autocorrelation, or persistence of negative affective states). In addition, there was a strong correlation between the burst-level random effects, where the correlation between the random NA_{t-1} slope and the NA_t intercept was $r = .57$, 95% CI [.44, .67]. This suggests that periods of heightened negative affect are accompanied by stronger consistency of negative affect across time.

The average marginal effect of rumination on the linear NA_{t-1} effect varied as a function of gender ($b = -0.05$, $p = .026$). In addition, there was a significant effect of gender and rumination on the quadratic NA_{t-1} effect ($b = 0.03$, $p = .001$). On average, drinking was associated with decreased negative affect for women, but not men. There was also a significant interaction between gender, drinking $_{t-1}$, and the NA_{t-1} quadratic effect ($b = 0.07$, $p < .001$). Finally, there was a significant interaction between gender, rumination, drinking $_{t-1}$, and NA_{t-1} ($b = -0.07$, $p = .039$). Hence, the persistence of negative affect across time varied as a function of gender, rumination, and drinking.

The interaction effects are depicted in Figure 1. The figure depicts the association between NA_{t-1} (x-axis) and NA_t (y-axis) as a function of: (A) drinking at $t-1$,

(B) gender, and (C) between-person differences in ruminative cognitive style. Steeper slopes signify a stronger autocorrelation between NA assessments across time. In addition, differences in expected values of NA_t for a given level of NA at $t-1$ can be seen as a function of levels of the moderators. As shown in the figure, drinking at $t-1$ had little effect on subsequent negative affect for men. In contrast, drinking at $t-1$ was associated with decreased negative affect at time t for women and this effect became increasingly pronounced as $t-1$ negative affect increased. This pattern suggests that drinking is negatively reinforced for women by reduction in subsequent negative affect. The effect of drinking on the negative affect autocorrelation indicates that drinking can attenuate emotional inertia, especially when negative affect is elevated among women. For example, when NA_{t-1} was moderate (i.e. a 4 on the 7-point scale), the linear Drinking $_{t-1} \times NA_{t-1}$ interaction was $b = -0.37$, $p < .001$ for women and $b = -0.001$, $p = .980$ for men, indicating that the consistency of NA across successive assessments decreased when women were distressed and consumed alcohol.

When not drinking, women's negative affect led to negative affect and the effects of rumination were fairly consistent across levels of negative affect. In contrast, men reporting low levels of rumination exhibited a steeper return to baseline when experiencing heightened negative affect, irrespective of drinking status. Rumination was associated with diminishing effects of drinking on negative affect among women. When women were moderately distressed, the effect of drinking on negative affect decreased from $b = -0.63$, $p < .001$ to -0.45 , $p < .001$ as rumination increased from $M - 1$ SD to $M + 1$ SD. In contrast, the effect of drinking on negative affect for men was insignificant for both those high ($b = 0.07$, $p = .406$) and low ($b = -0.09$, $p = .348$) in rumination.

Table 3. Multilevel autoregression analysis predicting negative affect at time t , random effects.

Random effects parameters	Estimate	SE	95% CI
Person			
NA_{t-1} slope σ_1	0.08	0.01	0.06, 0.11
Elapsed date slope σ_2	0.03	0.00	0.02, 0.04
Intercept σ_1	0.36	0.02	0.33, 0.40
$r(\sigma_1, \sigma_2)$	-0.15	0.20	-0.50, 0.25
$r(\sigma_1, \sigma_3)$	0.49	0.11	0.23, 0.68
$r(\sigma_2, \sigma_3)$	-0.24	0.12	-0.46, 0.01
Burst			
NA_{t-1} slope σ_4	0.17	0.01	0.16, 0.19
Intercept σ_5	0.09	0.01	0.08, 0.10
$r(\sigma_4, \sigma_5)$	0.57	0.06	0.44, 0.67
Day			
Intercept σ_6	0.07	0.01	0.06, 0.09
Residual: AR (1)			
rho	-0.15	0.01	-0.17, -0.13
SD(e)	0.53	0.00	0.53, 0.54

Notes: 263 persons, 43,111 signals. NA = negative affect.

Discussion

In the past decade, research on the temporal dynamics of affective experience has advanced considerably due to combined advances in technology (e.g. smartphones) and increasing accessibility of sophisticated data analytic approaches. Research has shed new light on the affective dynamics underlying depression (Koval et al., 2012; Koval et al., 2013), borderline personality disorder (Jahng et al., 2011), and alcohol use (Simons et al., 2014). Results of the current study add to existing knowledge on

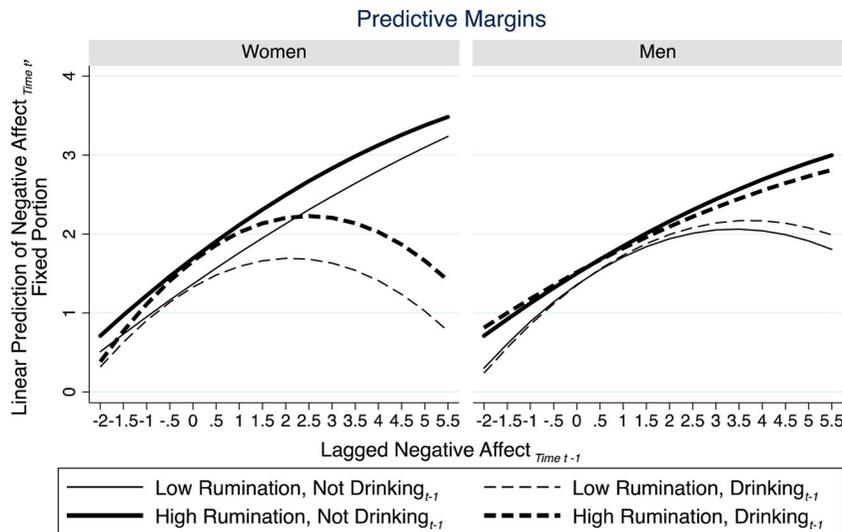


Figure 1. Within-person effects of negative affect_{*t-1*} (*x*-axis) on negative affect_{*t*} (*y*-axis) as a function of rumination, drinking_{*t-1*}, and gender. Low/high = $M \pm 1$ SD.

connections between rumination, negative affect, alcohol use, and emotional inertia, highlighting gender differences in these processes. Findings are discussed in the following sections.

Rumination and emotional inertia

As hypothesized, rumination at baseline was associated with higher negative affect over the follow-up period. However, the hypothesized effects of rumination on the persistence of negative affect across successive assessments were inconsistent and varied as a function of gender, drinking, and level of negative affect. As negative affect increased, women continued to experience strong associations between successive negative affect assessments, with rumination predicting heightened negative affect at each level. In contrast, for men, heightened negative affect was often followed by a return to baseline levels, and this was most pronounced for those reporting low tendency to ruminate. The pattern of relationships in Figure 1 is, perhaps, illustrative of the increased risk for depression among women (e.g. Kessler et al., 2007; Kuehner, 2003; Piccinelli & Wilkinson, 2000; Weissman et al., 1996). The effects are complex but the overall pattern is consistent with previous research suggesting that rumination may be a cognitive mechanism accounting for some of the increased risk for depression observed among women (e.g. Butler & Nolen-Hoeksema, 1994; Johnson & Whisman, 2013;

Nolen-Hoeksema, 2012). Furthermore, controlling for the other variables, rumination exhibited a somewhat stronger effect on the level of negative affect for women than men. However, as is apparent in the Figure, this pattern changes at times of greatest distress.

Emotional inertia may be conceptualized as the strength of associations between affect across time (Fairbairn & Sayette, 2013; Green et al., 1998; Kuppens et al., 2010). The random effects show a strong association between the level of negative affect (intercept) and the random autoregressive slope at the level of both the person and burst. That is, individuals who experience greater mean levels of negative affect exhibit greater autocorrelation of negative affect across time. Similarly, within individual, weeks characterized by heightened distress are associated with stronger associations between negative affect assessments moment to moment. This is consistent with findings from previous research in the laboratory as well as experience sampling (Green et al., 1998; Koval et al., 2013), that is, depression is associated with greater emotional inertia. Koval et al. (2013) examined the role of both affective lability and emotional inertia and found somewhat inconsistent findings in their laboratory and field research. Although we did not control for lability in this study, the results here, with a larger sample than previous studies, suggest that negative emotional inertia (i.e. strength of autocorrelation across time) has a

substantial association with level of negative affect and hence risk for depression. Interestingly, the data analysis demonstrates this effect at both the level of the person, potentially suggesting vulnerability, as well as the level of the measurement burst. The finding at the burst level is consistent with the perspective that peaks of negative affect may tend to be self-perpetuating, as they may signal importance of events. When an individual is having a “bad week”, they may become absorbed in focusing on the distress and its cause (Simons & Gaher, 2005), which is observed in stronger consistency in affect across time. This is in contrast to a “good week” where spikes in negative affect may reflect fleeting difficulties and have little bearing on successive emotion as the person remains mindful of the ongoing environment.

These effects of rumination and emotional inertia are hypothesized to increase risk for AUD. This premise is supported by three findings. First, rumination was positively associated with alcohol dependence symptoms at baseline. Second, there was evidence that the effect of drinking on emotional inertia varied as a function of rumination. This relationship was complex and varied as a function of gender. For women, but not men, the effect of drinking on emotional inertia was attenuated among those who tended to ruminate more. This pattern could promote increased alcohol consumption in an attempt to achieve the desired effect, underlying the observed association between rumination and alcohol dependence symptoms. Third, the findings indicate that alcohol can disrupt emotional inertia, highlighting the within-person mechanism contributing to the increased risk of AUD associated with rumination. Effects of drinking on emotional inertia are discussed next.

Drinking, negative reinforcement, and emotional inertia

The results add to the literature on associations between negative affect and alcohol use by examining the often-overlooked part of negative reinforcement models. That is, whether alcohol consumption in the natural environment is associated with subsequent reductions in negative affect. As is often the case in this area of research, the answer is sometimes, for some people. The results indicate that consuming alcohol was most clearly associated with reductions in negative affect when individuals were

experiencing greater distress. Multilevel models are often complex and analyses on associations between negative affect and drinking are rarely structured in such a way as to test nonlinear associations between negative affect and drinking. It is not uncommon for experience sampling studies to report null, or at least modest associations between negative affect and drinking (Hussong, 2007; Mohr, Arpin, & McCabe, 2015; Swendsen et al., 2000). Although the current study examines changes in negative affect rather than changes in drinking as the outcome, the results suggest that greater attention may need to be given to potential nonlinear associations between drinking and NA, with the most robust associations occurring when negative affect is elevated. In addition, the results highlight the potential importance of gender as a moderator, as significant effects were observed for women but not men. Consistent with previous research this suggests that negative reinforcement processes may be particularly important for the aetiology of AUD in women (Hussong, 2007; Lee, Kosterman, McCarty, Hill, & Hawkins, 2012; Lehavot et al., 2014). However, further research on gender effects is needed given the inconsistent findings on this in the literature (cf. Nolen-Hoeksema & Hilt, 2006; Simons, Gaher, Oliver et al., 2005; Witkiewitz & Villarroel, 2009).

Recent laboratory research has indicated that alcohol consumption disrupts emotional inertia, making individuals more responsive to the moment-to-moment stimuli in the social environment (Fairbairn & Sayette, 2013). Whereas rumination was shown to marginally increase emotional inertia in the current data, alcohol consumption served to disrupt emotional inertia, attenuating the autocorrelation of negative affect across time for women. This highlights a potential important aspect of the role of alcohol and affect regulation. The ability of alcohol to disrupt an entrenched pattern of rumination and negative arousal, freeing the person, if only for a while, to experience the external environment and to potentially benefit from positive stimuli in the social environment may be highly reinforcing. Indeed, the idea that alcohol intoxication affects mood by altering attention to salient environmental stimuli is a core feature of the attention allocation model (Fairbairn & Sayette, 2013; Steele & Josephs, 1988), and is posited to account for the wide ranging effects of alcohol from “crying alone in one’s beer” to being “happy, relaxed, and smiling”.

Limitations

Several limitations should be noted. First, although much of the rationale for the proposed analyses is based on vulnerability to depression, our study does not include depression as an outcome. Rather, we focus on level and autocorrelation of negative affectivity. Our measure of rumination was relatively simple and does not capture the multidimensional nature of rumination (Smith & Alloy, 2009). Nonetheless, the pattern of results provides strong evidence for the validity of the measure. Although heavy drinking young adults are a unique population. Further research is needed to determine if the results generalize to other populations that vary in the developmental stage, drinking norms, or clinical severity. Finally, negative reinforcement of alcohol use inherently involves both the effects of negative affect on drinking as well as effects of drinking on negative affect. Here, we focus on the latter part of the equation.

Summary

Though it may come as no surprise to the informed reader, the results suggest that rumination perpetuates negative affect and alcohol can provide quick reductions in negative affect. These generalities aside, the results provide an intriguing analysis of the time course of negative affect. During periods of heightened affect, negative affect begets negative affect, emotional experience sinks into inertia. In contrast, during periods of well-being negative affect is changeable moment-to-moment, as the individual is ostensibly engaged in the breadth of experience in the natural environment. The time course of negative affect for women is consistent with the epidemiological data indicating risk for depressive disorders. This vulnerability appears, in part, tied to the effects of rumination. Men in this sample appeared to have negative emotional experiences that were fleeting and less likely to be sustained over time. When men did experience heightened negative affect, rumination had a more pronounced effect with only those endorsing elevated levels of rumination showing a pattern of sustained negative affectivity. The findings regarding alcohol also emphasize the increased risk among women in this sample for drinking for negative reinforcement. The results not only indicate that rumination is correlated with symptoms of alcohol dependence, but illuminate the underlying risk mechanism at the within-person level. The findings suggest that

alcohol may disrupt emotional inertia, freeing the individual to experience the emotional richness of the moment, a potentially highly attractive immediate effect with the consequent liability of contributing to the development of problematic alcohol use patterns.

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