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The role of affect, emotion management, and attentional bias in young adult drinking: An experience sampling study

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Abstract

Rationale Coping with negative affect is central to several prominent etiological models of alcohol use. These models posit that alcohol use becomes negatively reinforced due to its ability to alleviate negative affect. However, there have been mixed findings when testing this association at the event-level.

Objectives The current experience sampling study sought to clarify this by testing if (1) within-person changes in the perceived difficulty of managing emotional distress is a significant predictor of alcohol consumption, over and above levels negative and positive affect and (2) whether acute changes in affective experiences give rise to increased attentional bias toward alcohol-related cues in the environment and if attentional bias mediates the association between difficulty managing emotions and alcohol consumption. Participants were 92 college students aged 18–25, who drink alcohol at least moderately.

Methods Participants completed 28 days of experiencing sampling measures on their mood, difficulty managing emotions, alcohol-related attentional biases, and drinking.

Results Findings showed that neither negative affect nor difficult managing emotions had significant effects on alcohol use. However, positive affect exhibited the expected associations with both attentional biases and drinking. State positive affect predicted acute increases in attentional biases and drinking, whereas trait positive affect was inversely associated with trait attentional biases and alcohol use. Alcohol-related attentional biases exhibited significant within-person variance; however, its relationship with drinking was only significant when the constructs were assessed concurrently at night and did not mediate the relationship between affect and alcohol use.

Conclusions Results highlight the importance of positive affect in this population.

Keywords Positive affect · Negative affect · Emotion dysregulation · Alcohol-related attentional bias · Alcohol consumption · Experience sampling · Ecological momentary assessment

Negative affective functioning figures prominently in many etiological models of alcohol use (Kassel and Veilleux 2010). Theoretical accounts of the relationship between affect and drinking suggest that alcohol is often consumed as a form of affect regulation due to the positive or negative reinforcing qualities of alcohol (McCarthy et al. 2010; Sher and Grekin 2007). A central premise of these models is that those who use alcohol to regulate their emotions become motivated to consume alcohol when they experience heightened levels of affective arousal (Baker et al. 2004; Sher and Grekin 2007). Consistent with this is research demonstrating positive event-level associations between negative affect (NA) and subsequent drinking (e.g., Armeli et al. 2000; Mohr et al. 2005; Simons et al. 2014; Swendsen et al. 2000). While there is strong theoretical rationale and empirical evidence for the within-person association between NA and alcohol consumption, it is not uncommon for experience sampling studies to report null (Dvorak and Simons 2014), modest (Hussong 2007), or even inverse associations between NA and drinking (Dvorak et al. 2014; Simons et al. 2010). Hence, there are some unanswered questions regarding the relationship between NA and

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alcohol consumption, such as (1) what form of NA is the optimal predictor of alcohol use, and (2) what mechanism links NA to alcohol consumption.

Affect dysregulation and alcohol use

Heightened levels of NA are but one potential sign of dysregulated affect. Research has identified the dynamic time course of affect as an important indicator of dysregulation (Ebner-Priemer et al. 2009; Simons et al. 2014). Additionally, research suggests that high intensity, rapid fluctuation in emotion is predictive of alcohol use problems beyond level of affect (Simons et al. 2014). NA intensity is associated with the experience of struggling to manage emotional responses (Salters-Pedneault et al. 2006; Veilleux et al. 2014); however, it may or may not actually prompt efforts to consciously regulate it, depending on other important contextual factors such as situational demands and features of the eliciting stimuli (Aldao and Tull 2015). Instead, researchers have observed using between-person methods that it is the subjective experience of difficulty regulating NA that appears to be the more proximal predictor of coping-motivated drinking behavior, rather than NA intensity (Veilleux et al. 2014). This is consistent with negative reinforcement models of substance use motivation (McCarthy et al. 2010), that suggest that affective distress leads to the recruitment of cognitive control processes responsible for adaptive action (e.g., emotion regulation, attentional bias) that, in turn, trigger the conscious drive or motivation to use. Therefore, even though a person may be experiencing high levels of NA, it is not until their experience of NA exceeds their ability to manage it that substance seeking ensues. This may happen at varying levels of awareness, depending on an individual's drinking history. Indeed, recent psychometric work on a state version of the Difficulties in Emotion Regulation Scale has identified perceived difficulty managing emotions as a time-varying component indicative of emotional dysregulation (Lavender et al. 2015). Importantly, to date, this subjective experience of struggling to manage one's emotions has not been examined as a predictor of alcohol involvement at the event-level, which may help clarify the role of affective functioning in alcohol use. Thus, a major goal of the current study was to test if perceived difficulties in managing affect predict alcohol consumption, over and above negative affect, at the event-level.

Attentional bias: a mechanism linking affect and alcohol use

Another facet of the NA-alcohol use stimulus-response chain that is not entirely clear is how NA translates into alcohol use. One widely accepted mechanism is conscious self-medication (e.g., Sher and Grekin 2007); yet, NA serves as more than simply a stimulus for coping. Instead, it also triggers biases in cognitive processing, which are, at least in part, responsible for the relationship between NA and alcohol use (Baker et al. 2004; Birch et al. 2006). Alcohol-related attentional bias (AAB) is the propensity for alcohol-related stimuli to capture the attention of the sensory systems at the expense of processing competing stimuli (Field and Cox 2008). AABs have traditionally been considered a relatively stable individual difference factor that indexes use severity (Field and Cox 2008). Despite this conceptualization, between-person laboratory studies show that compared with a control condition, laboratory-induced NA produces significant increases in AAB, but only among those who endorse mood-congruent dinking motives (Field and Powell 2007; Field and Quigley 2009). This suggests that AABs are plastic and vary with affective states. However, these findings have come under increased scrutiny for having poor reliability and failing to replicate in the lab at the within-person level (Ataya et al. 2012; Emery and Simons 2015; Jones et al. 2018).

Accordingly, some researchers have called for a shift in the environment where these biases are measured (Christiansen et al. 2015) and research shows that it is possible to successfully administer reaction-time-based measures of attentional bias on electronic devices in the participant's natural environment (Szeto et al. 2019; Waters et al. 2012; Waters and Li 2008). Results from these studies show that attentional biases to substance-related cues measured using mobile technology increase with fluctuating appetitive states, such as craving, leading to more use (Marhe et al. 2013). Taken together, this suggests that a substantial portion of the variance seen in attentional biases lies at the within-person level, rather than the between-person level. Thus, AAB may be an ideal within-person mediator of the relationship between difficulty managing emotions and alcohol involvement. That is, as difficulty managing emotions increases the salience of alcohol-related cues in the environment will increase, promoting corresponding increases in drinking behavior. Hence, another goal of the current study was to test if event-level changes in AAB, measured using experience sampling methodology (ESM), mediate the relationship between within-person changes in difficulty managing emotions and drinking.

Positive affect: within- and between-person associations

In addition to the alleviation of NA, many individuals report drinking because of its positive mood enhancing effects (Cooper et al. 2015; Simons et al. 2005a) and alcohol is commonly used to facilitate social interaction and in celebratory situations, especially in young adults (Cooper et al. 2015; Glindemann et al. 2007; Neighbors et al. 2007). As such, positive affect (PA) exhibits significant positive associations with alcohol use in situations where social drinking is the predominant pattern (Duif et al. 2019; Mezquita et al. 2010; Simons et al. 2005a). Accordingly, within-person studies of young adults consistently find a positive association between increases in PA and subsequent alcohol consumption (Colder et al. 2010; Dvorak et al. 2018; Simons et al. 2010; Simons et al. 2014). However, between-person studies demonstrate that low trait PA is associated with high levels of alcohol use (Colder and Chassin 1997; Simons et al. 2014; Wills et al. 1999), which is compatible with self-medication models in that alcohol use is utilized as a coping strategy in dealing with aversive low PA (Colder et al. 2010). Taken together, this research indicates that the relationship between positive affect and alcohol use is discordant at the within- and between-person levels, with state positive affect predicting acute increases in drinking, while trait positive affect is inversely associated with alcohol involvement (Colder et al. 2010; Simons et al. 2014). This discordance highlights the complexities of affect-motivated drinking and its associations with an individual's drinking trajectory over time. Positive reinforcement motivated alcohol use (i.e., social and enhancement motives) appears to be closely related to the initiation of use (Kuntsche and Müller 2012; Patrick and Schulenberg 2011) and subsequent heavy episodic drinking (Cooper et al. 2015; Kuntsche et al. 2006) that decreases with age (Littlefield et al. 2010). Moreover, positive reinforcement is often only associated with drinking problems indirectly via consumption (Cooper et al. 1995; Kassel et al. 2000; Molnar et al. 2010; Simons et al. 2005a).

In sum, it is clear that positive reinforcement plays an important role in and is a strong predictor of alcohol consumption in young adult college students. Thus, any study on affect-motivated drinking would be remiss not to include positive affect as an important component of their predictive model. Yet, even though college student drinking is regularly associated with enhancement of PA, rather than coping with NA (Cooper et al. 1995; Simons et al. 2005a), negative reinforcement motives remain an important part of young adult college student drinking (Cooper et al. 2015; Park et al. 2004). There is evidence that negative affect exhibits unique associations with alcohol-related problems over and above use (McCreary and Sadava 2000; Park and Grant 2005; Simons et al. 2005a; Simons et al. 2014) and that negative reinforcement becomes increasingly important over time (Cooper et al. 2008; Koob 2013; Littlefield et al. 2010; Patrick and Schulenberg 2011; Rutledge and Sher 2001; Wills et al. 1999). Accordingly, there appears to be a substantial subsection of college students that still drink to cope even after accounting to enhancement-related use and it is these people that are at greatest risk for problems. Therefore, another goal of the current study was to test if perceived difficulties in managing emotions predict alcohol consumption, over and above event-level positive and negative affect as well as to examine the relationship between PA and our other variables of interest.

The current study

The study is innovative in both method and theory and applies a newly developed measure of state-based affect dysregulation to the study of substance use (Lavender et al. 2015). In the past decade, there has been increasing recognition of the need to assess within-person variation in affect dysregulation to better characterize its associations with behavior at the event-level (Lavender et al. 2015; Simons et al. 2005b; Simons et al. 2014). The model proposes that within-person change in the perceived difficulty of managing emotional distress is an optimal predictor (relative to level of NA) of alcohol seeking behavior. In addition, the study utilized new advances in mobile technology to assess state-based changes in AABs. The study aimed to advance the understanding of the NA-alcohol relationship by testing the hypothesized mediating role of attentional biases in the natural environment. Importantly, relatively little is known about the time course of the relationship between state-based fluctuations in AABs and alcohol consumption in the natural environment. It is possible that AAB during the day is prospectively associated with alcohol consumption later that night; however, it is also possible that changes in AAB and drinking influence each other dynamically in the moments just before and/or during drinking episodes. This too is an important gap and as such this study sought to explore this by estimating two models, one where daytime AAB prospectively predict nighttime drinking and another where change in AABs from day to night predict nighttime alcohol use. In summary, this experience sampling study sought to: (1) test if event-level increases in difficulty managing emotions during the day are associated with subsequent drinking at night, over and above the effects of daytime positive and negative affect, (2) test whether event-level changes in AABs, mediate the relationship between within-person changes in difficulties managing emotions and drinking, and (3) explore the optimal lag to measure the influence of state-based changes in AAB on drinking.

Hypotheses

Based on previous research, it was hypothesized that PA would be related to increased drinking at the within-person level and decreased drinking at the between-person level (Simons et al. 2014). Difficulty managing emotions was hypothesized to have significant positive effects on drinking at both the within-person and between-person levels. Given the association between difficulty managing emotions and negative affective intensity (Lavender et al. 2015), NA was expected to exhibit a similar pattern of relationships, but was expected to be a non-significant predictor in the model after accounting for the effects of difficulty managing emotions. Finally, taking into account theory (Baker et al. 2004; Field and Cox 2008; McCarthy et al. 2010), and longitudinal as well as cross-sectional research on the effects of cognitive biases on alcohol consumption (Hallgren and McCrady 2013; Janssen et al. 2015; Lindgren et al. 2015), AAB was hypothesized to be positively associated with drinking at both the within-person and between-person levels.

Method

Participants

A sample of 102 undergraduate students age 18–25 who drank at least moderately (i.e., ≥ 7 standard drinks a week for women and ≥ 14 standard drinks a week for men; U.S. Department of Health and Human Services and U.S. Department of Agriculture 2015) was recruited and enrolled in the ESM portion of the study. However, nine participants dropped out of the study within the first few days due to phone compatibility issues, application malfunctions, or personal issues. One participant did not complete any morning surveys and thus was excluded from the analysis given that the primary outcome was missing. This made for an analytic sample of 92 participants (women = 58, 63%; age M = 20.17, SD = 1.37). Ninety-seven percent of the sample was White, 1% Asian, 1% Multiracial, and 1% other. Ninety-six percent were non-Hispanic.

Power analysis

An a priori power analysis was conducted via computer simulation, using the Monte Carlo feature of Mplus 8.1 (Muthén and Muthén 2017). Although the planned analysis used a count outcome, the power analysis was conducted assuming normal distributions so that traditional effect size conventions could be used. The majority of the variance (75%) was specified at the within-person level (Marhe et al. 2013; Zvielli et al. 2014). The focal effect of interest in this study was the within-person indirect effect of difficulty managing emotions on alcohol consumption via AAB. Unfortunately, previous research has not examined many of the paths this study intends to estimate using multilevel analyses; however, estimates can be extrapolated from experimental and survey research of similar constructs. These studies suggest that difficulty managing emotions will exert a moderate effect on AAB (0.3–0.4; Coskunpinar et al. 2013; Garland et al. 2012) and AAB will exhibit moderate effect on alcohol use (0.3–0.4; Field and Eastwood 2005; Garland et al. 2012; Gladwin 2016). Yet, given the lack of a strong basis for estimating the comparable within-person effects, the power analysis was done with effects ranging from small effects ($\beta = 0.05$) to moderate effects ($\beta = 0.30$) for both the effect of difficulty managing emotions on AAB as well as AAB on alcohol use. The literature suggested somewhat smaller effects for difficulty managing emotions at the between-person level (Lavender et al. 2015); therefore, a relatively small effect (0.2) was utilized at this level. Results of the power analysis using 10,000 replications indicated a sample of 90 individuals with 28 days of experience sampling would be sufficiently powered to detect the hypothesized indirect effects of difficulty managing emotions on alcohol consumption via state-based changes in AAB at the within-person level for effects of 0.07 or greater. Power estimates for effects 0.06 or below ranged from 0.34–0.61; whereas with power estimates for effect 0.07 or higher ranged from 0.83 to 1.00. The remaining within-person direct effects were all sufficiently powered across all effect sizes with power estimates ranging from 0.81 to 1.00. The power for the between-person direct effects ranged from 0.79 to 0.93. The between-person indirect effect was underpowered (0.58). However, testing the significance of this indirect path is not a focal point of the study and thus should not affect the study's aims. Importantly, the final model will have a substantial number of covariates (see analysis plan), such as day of the week, positive and negative affect, and gender, which will account for additional residual variance not estimated in this model, effectively increasing power above that seen here.

Procedure

Recruitment and initial screening

Participant recruitment took place through announcements in classes, flyers, email announcements, and the university research pool. Participants completed an initial online consent form and baseline assessment. Participants meeting drinking level eligibility criteria were invited to participate in the ESM study.

Experience sampling study

After informed consent, participants were trained to use an ESM application deployed on participants' personal cellular phone. Participants were assessed for 28 consecutive days. The ESM application was programed with mEMA software (Tuomenoksa 2013) developed by ilumivu Inc. The sampling protocol is derived from Simons and colleagues (Simons et al. 2014). The program generated 8 prompts for participants to complete brief ~ 2-min assessments about participants' behavior in the past 30 min at random times within 2-h blocks between 10:00 a.m. and 2:00 a.m. The ESM assessments included measures of affect, difficulty managing emotions, alcohol-related attentional biases, and alcohol consumption in that order. This ordering was designed to minimize any potential priming effects questions about alcohol consumption could exert on AAB. Participants were asked to complete random assessments during waking hours and could skip prompts when they were sleeping or otherwise do not wish to be disturbed (e.g., taking an exam). In addition to the random assessments, participants were asked to complete a morning assessment shortly after waking each day. The morning assessment had additional questions regarding alcohol use during the previous evening to assess total drinks consumed. To establish the temporal association between affect, AAB, and drinking, the data was structured such that the daytime affect and AAB assessment interval (i.e., 10 a.m.–5 p.m.) precedes the subsequent nighttime AAB and drinking assessment interval (5 p.m. onward). Individuals who participated in the ESM study received payments contingent on response rates, $0.20 per survey up to $50. Also, each ESM assessment a participant completed provided them with an entry into a monthly drawing for additional 100. If a participant completed all the ESM assessments, they received 50 and 252 entries (9 ESM assessments x 28 days) to win an additional $100.

Baseline measures

Demographic information

Participants were asked to indicate their gender, age, year in school, race, and ethnicity.

Alcohol consumption

Alcohol consumption was assessed using the Modified Daily Drinking Questionnaire (MDDQ; Dimeff et al. 1999). The MDDQ consists of a grid representing the 7 days of the week; participants indicate the typical number of standard drinks consumed on each day in a normal week over the past 90 days (one standard drink = 12 oz. beer, 5 oz. wine, or 1.5 oz. liquor).

Experience sampling measures

Affect

Positive and negative affect in the previous 30 min was assessed by items from subscales of the PANAS-X (Watson and Clark 1999) and Larsen and Diener's affect circumplex model (Larsen and Diener 1992). Negative affect was represented by 9-items representing three dimensions: sadness, anxiety, and anger: sad, blue, downhearted, nervous, jittery, anxious, angry, hostile, and irritable. Items were rated on 7-point scales ranging from 1 = not at all to 7 = extremely. Positive affect was assessed by 5 items from the joviality subscale: happy, joyful, excited, energetic, and enthusiastic. Previous research supports the internal consistency and criterion validity of these scales assessed by experience sampling (Csikszentmihalyi and Larson 1992; Simons et al. 2014). Daytime positive affect and negative affect was defined as the participant's mean across signals (i.e., random assessments) between 10 a.m. and 5 p.m. Daytime positive affect and negative affect was used in the analyses. We calculated reliability of the positive and negative affect scales at the within- and between-person level using McDonald's Omega (McDonald 2013) following procedures of Geldhof et al. (2014). McDonald's omega (ω) is an index of internal consistency that uses a factor analytic approach to partition the common variance among the items from the unique variance and determine the general factor saturation of the test. It is the ratio of the common variance to the total variance (common and unique; Dunn et al. 2014). The positive affect scale exhibited good reliability at both the within- ($\omega = .92$) and between-person ($\omega = .98$) levels. The negative affect scale also exhibited good reliability at both the within- ($\omega = .83$) and between-person ($\omega = .89$) levels.

Alcohol consumption

Alcohol consumption was assessed in two ways over the course of the ESM protocol. The first was during random assessments. Here participants reported the number of drinks they consumed over the past 30 min on an 8-point scale (0–7 or more drinks). The other was during morning assessments where participants were asked, "How many drinks did you consume last night?" which they responded to on a 13-point scale of 0–25 or more, with increments aside from the end points representing a 2-drink range (e.g.., 0, 1–2, 3–4, 5–6, etc.). Definitions of standard drinks were provided during the ESM training. Total drinks assessed during morning assessment was used as the outcome measure. Validity of this alcohol assessment is supported by significant associations with transdermal alcohol monitoring (Simons et al. 2015).

Difficulty managing emotions

Difficulty managing emotions in the past 30 min was assessed by the Limited Ability to Modulate Current Emotional and Behavioral Responses Subscale (Modulate) of the State Difficulties in Emotion Regulation Scale (S-DERS; Lavender et al. 2015). The Modulate subscale consists of 7-items on a 5-point scale ranging from 1 = not at all to 5 = completely (sample item: "My emotions feel overwhelming"). Previous research shows support for the reliability and validity of the S-DERS as a state-based measure of emotion regulation difficulties. Daytime Modulate scores were defined as the participant's mean across signals between 10 a.m. and 5 p.m. Daytime Modulate scores were used in the analyses. As with NA and PA, we calculated the reliability of the Modulate scale of the S-DERS using McDonald's Omega (McDonald 2013) at the within- and between-person levels (Geldhof et al. 2014).

The Modulate subscale exhibited good reliability at both the within- ($\omega = .82$) and between-person ($\omega = .91$) levels.

Alcohol-related attentional bias

AAB was assessed with an adapted in situ version of the alcohol-Stroop task (Marhe et al. 2013; Waters and Li 2008) administered during the random assessments. This was modeled after the drug counting Stroop which is regularly used to assess attentional bias for drug-related cues (e.g., Goldstein et al. 2007; Kennedy et al. 2014; Kilts et al. 2014). At each signal, participants responded to 3 practice trials, followed by 1 of 3 randomly selected 30 trial blocks. The entire task took approximately 30–45 s. In this version of the alcohol-Stroop task, participants were told that they would see sets of 1–4 identical words on the screen in a vertical array and presented in capital letters. The words would remain on screen until the participant responded. Participants were instructed to indicate how many words were in each array as quickly as possible by pressing one of the response options listed on the screen, regardless of what the words were. Within each trial block, the application randomly selected (without replacement) from a series of matched alcohol-related and neutral words (words were matched for frequency of use and length), while capturing the reaction time (RT) of each response. After the task was complete, a single item asked participants to report if they were interrupted during the task (e.g., by the telephone ringing or by somebody trying to talk to them; Waters and Li 2008).

The core idea behind this task is that individuals who drink alcohol regularly tend to have larger Stroop effects when words are related to alcohol, relative to words from a neutral category (Cox et al. 2006). Larger Stroop effects on trials with the alcohol-related words suggest automatic processing of the word's semantic content, which impairs the speed of responses. Thus, these differences in speed between the two word categories are an index of the disproportionate sensory and cognitive processing found in attentional bias (Field and Cox 2008). AABs were calculated using the trial-level bias score (TL-BS; Zvielli et al. 2014). TL-BS is computed by subtracting temporally adjacent pairs of alcohol trial and neutral trial RTs. Specifically, each neutral trial is matched with replacement to an alcohol trial that is temporally as close as possible and no further than five trials away (before or after) from the neutral trial. After matching trials in this way, RTs from the neutral trial are subtracted from their matched alcohol trial, creating a time series of difference scores (i.e., TL-BSs) per signal per participant. This quantification of attentional bias has demonstrated good criterion validity for alcohol- (Gladwin 2016) and drug-related cues (Zvielli et al. 2014). Additionally, this measure has demonstrated increased reliability compared with traditional mean-based measures of attentional bias (Zvielli et al. 2014). The peak TL-BS in a trial block was used as the metric of AAB. Daytime AAB scores were defined as the participant's mean of the peak TL-BSs across signals between 10 a.m. and 5 p.m.; whereas, nighttime AAB was the mean across signals between 5 p.m. and 2 a.m. We estimated the internal reliability of peak TL-BSs using split-half reliability following procedures of Szeto et al. (2019) to test mean-based bias scores. In this approach, trial blocks (1 at each signal) were split into two halves representing odd and even trials. Then, peak TL-BSs were created from the odd and even halves and correlated. Peak TL-BSs exhibited modest split-half reliability, $r_{\text{Spearman–Brown Prophecy}} = .26$, $p < .001$ which is consistent with TL-BSs assessed in the laboratory (Zvielli et al. 2014).

Analysis plan

The data were analyzed with multilevel structural equation modeling (MSEM) using Mplus 8.1 (Muthén and Muthén 2017) with the maximum likelihood robust estimator (MLR) following that of Simons et al. (2014) in which the days (level 1) are nested within the person (level 2). The models contained event-level (i.e., varying within-person across days) constructs with random intercepts (daytime NA, daytime PA, daytime difficulty managing emotions, AAB) predicting nighttime number of drinks. Affect, difficulty managing emotions, and AAB scores were continuous variables. Nighttime alcohol consumption was specified as having a negative binomial distribution. Random variation in the slopes was tested sequentially using a model building approach (i.e., increasing model complexity in steps), such that each potential random slope was examined individually for significance. None of the slopes had substantial random variance and thus all slopes were estimated as fixed effects to simplify model estimation.

At level 1, six orthogonal day of the week indicators and elapsed days were included as exogenous covariates with direct paths to all endogenous variables (e.g., PA and alcohol consumption). The inclusion of the day of the week addresses daily variation in mood and drinking and may reduce serial auto-correlation across days (cf. Mohr et al. 2001). Inclusion of the number of days elapsed since initiating the study controls for change over time (e.g., reactivity to the assessment protocol). At level 2, gender was included as an exogenous covariate with a direct path to alcohol consumption and correlated with the affect-related variables. The relationship between the covariates and AAB varied depending on the model. In the model that only included daytime AAB, gender had a direct path to daytime AAB; whereas in the model that included both daytime and nighttime AAB, gender had a direct path to nighttime AAB and was correlated with daytime AAB. The residuals of PA, NA, and difficulty managing emotions were allowed to covary at level 1 and the constructs were allowed to covary at level 2. In the nighttime AAB model, daytime AAB was treated similarly to the affect-related variables such that the residuals of PA, NA, difficulty managing emotions, and daytime AAB were allowed to covary at level 1 and the constructs were allowed to covary at level 2.

The affect, difficulty managing emotions, AAB, and alcohol consumption variables were designated as having variance at both the between- and within-person levels. When using the MSEM approach (Preacher et al. 2010), this designation creates latent between- and within-person variables from repeated measures data. That is, the between-person affect, difficulty managing emotions, and AAB are unobserved latent trait factors estimated from the repeated measures data (i.e., latent estimates of the person mean across assessments). The within-person affect, difficulty managing emotions, AAB, and alcohol consumption measures are unobserved latent state factors estimated from the repeated measures data (i.e., latent person-mean centered within-person variables). The MSEM approach reduces bias in estimates of the between-person effects. As such, MSEM leverages the benefits of intensive repeated measurement inherent to experience sampling for the testing of the between-persons model (Preacher et al. 2011; Preacher et al. 2010). Thus, this approach is ideal for modeling the complex associations between time-varying risk factors that contribute to high-risk drinking episodes. Furthermore, MSEM allows for testing mediation models at different levels of measurement (i.e., between- and within-person; Preacher et al. 2010). In the current analysis, we tested what is referred to as a 1–1–1 model (Preacher et al. 2010) where the predictors (positive affect, negative affect, and difficulty managing emotions), mediator (AAB), and outcome (alcohol consumption) are all measured at level 1. Importantly, when testing a 1–1–1 model, estimates of the mediated effects can be derived for both level 1 and level 2.

Prior to testing the indirect effects, we tested for additional direct effects of daytime affect and difficulty managing emotions on alcohol consumption to determine if these variables exhibit associations with the outcome that are not mediated by AAB. This effectively tests whether the hypothesized structure is tenable by estimating a series of alternative models that determine whether direct effects of PA, NA, and difficulty managing emotions on alcohol use are non-significant (i.e., zero). Importantly, in models that require numeric integration (such as this), traditional model fit indices used to interpret the fit of structural equation models (e.g., CFI, RMSEA, SRMR, and χ^2) have not been developed. Instead, an alternative method for assessing the fit of each model needs to be employed (Maslowsky et al. 2015; Satorra and Bentler 2010), whereby nested models are compared using a likelihood ratio test. This is operationalized as the relative fit of the base model and the expanded alternative model. We also present incident rate ratios (IRR) for paths to drinking to illustrate effect sizes.

Data handling and preparation

Preliminary analyses were conducted to determine the ranges and distributions of all variables and scatterplots of all variables were inspected to evaluate linearity. Examination of between-person influence statistics (e.g. Cook's D) suggested that three subjects were exerting significant influence on model fit. These subjects were independently examined. Examination of these subjects' person-day data revealed seventeen (0.008% of person-days) potential unreliable responses (e.g., Cook's $D > 1$). These observations and subjects were iteratively removed, and the analysis rerun. These alterations did not result in any changes to the findings or subsequent interpretations and thus were retained in the final models.

For the attentional bias scores, RT data with errors (2.85%), incomplete trials (0.18%), or where participants reported being interrupted (13.12%) were excluded. Trials with RTs 3.29 SD above an individual's mean (1.05%) as well as scores shorter than 200 ms (0.11%) were discarded as outliers (Field and Quigley 2009). Extremely fast responses increase the chance that the response is anticipatory or premature and the slow responses may indicate that the participant was either distracted or attended to the stimuli rather than responding immediately as instructed. Errors, interruptions, and outliers accounted for 18.46% of the RT data. Trial-level difference scores were calculated from the remaining 244,672 observations (80.43%). After this, we also conducted the median absolute deviation (MAD) method of outlier removal (Kline 2015) for the individual TL-BSs. The MAD method involves calculation of median value of an individual's TL-BS distribution and subtracting this from each score to create a series of absolute values. The median of these values is then multiplied by 1.483 to calculate the MAD. The absolute values in each participant's distribution were then divided by the MAD. If resulting quotient was above 2.58, it was flagged as an outlier (9.88%). The remaining 229,651 TL-BSs (75.49%) were used to calculate the signal level metric of AAB (i.e., peak TL-BS).

Results

Descriptive statistics

There was a total of 2576 possible person-days (i.e., 92 participants × 28 days). However, due to various difficulties in data collection (e.g., application malfunctions, machine damage or loss, operator error, participant attrition, etc.) the dataset contained 1985 person-days (77.06% of the possible person-days). Participants completed surveys on an average of 21.58 days (SD = 8.36). Participants had adequate compliance with the random in situ assessments completing 66.65% (n = 8939) of eligible signals (i.e., times when the app was functional, and the participant could therefore receive the signal).

Participants had good compliance with the morning assessments completing 88.01% ($n = 1643$) of morning assessments across eligible person-days. We restricted the person-days included in the analysis to those days in which participants completed at least 3 random assessments. This was selected to increase reliability of the estimates and to exclude days with poor protocol adherence. Thus, there were 1709 person-days (86.10% of total person-days) available for full analysis.

Overall participant compliance was inversely correlated with self-reported weekly alcohol consumption (M = 19.21, SD = 12.72) on the MDDQ at baseline ($r = -0.21$, $p = .042$), showing that those with higher alcohol consumption prior to beginning the ESM study exhibited poorer compliance to the ESM protocol. Compliance was not related to between-person level aggregates of affect, difficulty managing emotions, attentional bias, or drinking during the study ($ps > .07$). Participants reported drinking on 37.41% ($n = 547$) of analysis days. Participants' number of drinks across days ranged from 0 to 25 or more. Participant's averaged 5.73 (SD = 4.69) standard alcoholic beverages per drinking day. Descriptive statistics as well as correlations for level 1 and level 2 variables (i.e., zero-order correlations) are presented in Table 1. The subject-means for each of level 1 variables were used to create level 2 aggregates.

MSEM analyses

The intraclass correlation was .45 for negative affect, .56 for positive affect, .55 for difficulty managing emotions, .22 daytime AAB, and .18 nighttime AAB, indicating that 45% to 56% of the variance in the daytime affect-related variables was at the between-person level and 55% to 44% within-person. Likewise, this denotes that 22% of variance in daytime AAB was at the between-person level while 78% was at the within-person and 18% of nighttime AAB was at the between-person level and 82% was at the within-person. This finding supports the stance that AAB is a time-varying construct appropriate for event-level methods and analysis. Intraclass correlation is not available for the count outcome.

Direct effects of affect-related variables on alcohol consumption

To test the hypothesized associations between the daytime affect-related variables and nighttime drinking, a multilevel structural model was estimated where daytime NA, PA, and difficulty managing emotions all had direct paths to nighttime alcohol consumption. Alcohol consumption was specified as a count with a negative binomial reference distribution. At level 1, six orthogonal day of the week indicators and elapsed days were included as exogenous covariates with direct paths to all endogenous variables (e.g., PA and alcohol consumption). The residuals of the affect-related variables were all allowed to covary at level 1. At level 2, gender was included as an exogenous covariate with a direct path to alcohol consumption and AABs and correlated with the affect-related variables. All affect-related variables were allowed to covary with each other at level 2. In a model such as this, all the hypothesized paths are

Table 1 Level 1 and level 2 descriptive statistics and correlation matrices

Variables	M (SD)	Skew	1	2	3	4	5	6	7	8	9	M (SD)	Skew
1. Gender	58F/34M		-	-	-	-	-	-	-	-	-		
2. Age	20.17 (1.37)		.30**	-	-	-	-	-	-	-	-		
3. Negative affect	1.68 (0.52)	0.92	− .12	− .13	-	− .28***	.59***	− .02	− .06	.01	-	1.61 (0.75)	1.91
4. Positive affect	3.33 (1.00)	0.45	.14	.09	− .21*	-	− .17***	.06*	.05*	.15***	-	3.33 (1.32)	0.39
5. Difficulty managing emotions	1.31 (1.00)	0.45	− .07	− .31**	.59***	− .14	-	.01	− .03	− .03	-	1.30 (0.52)	2.73
6. Day alcohol attentional bias	262.57 (74.66)	1.07	− .04	− .01	−.14	.07	− .27**	-	.08**	.001	-	258.64 (139.05)	2.03
7. Night alcohol attentional bias	269.67 (69.89)	0.43	− .08	− .18	.002	− .14	.03	.53***	-	.08**	-	269.08 (133.48)	1.81
8. ESM alcohol consumption	2.58 (2.41)	1.75	.36***	.07	.13	.01	.04	− .01	−.17	–		2.14 (3.98)	2.54
9. Baseline alcohol consumption	19.22 (12.72)	1.62	.46***	− .05	.12	− .001	.07	.01	.12	.53***	-		

$N = 92$. Level 1 observations ranged from 1571 to 1169 person-days. To the left of the diagonal are the between-person level variables and to the right are the within-person levels. L1 variables are "states" varying within-person across time and L2 are dispositional characteristics aggregated from multiple state assessments (i.e., "traits"). Gender (men = 1, women = 0). Difficulty managing emotions = modulate subscale of the S-DERS. Alcohol-related attentional bias = alcohol counting Stroop. Baseline alcohol consumption = MDDQ.

*$p < .05$

**$p < .01$

***$p < .001$

estimated simultaneously, and each path coefficient represents a semi-partial estimate. Final model estimates are in Table 2.

Consistent with hypothesis, at the day-level (L1), there was a significant within-person association between daytime positive affect and greater nighttime alcohol consumption (IRR = 1.26). In practical terms, this means that for every 1 unit increase in daytime PA (M = 3.33; see Table 1 for descriptive statistics), participants' drinking increased by 26%. However, contrary to hypothesis, daytime difficulty managing emotions was not associated with nighttime alcohol consumption. Daytime negative affect was also not associated with nighttime alcohol consumption, yet this null effect was expected after accounting for the effects of difficulty managing emotions. As anticipated, L1 residuals of daytime positive affect inversely covaried with both negative affect (cov = − 0.26, $p < .001$) and difficulty managing emotions (cov = − 0.10, $p < .001$); while daytime negative affect and difficulty managing emotions positively covaried (cov = 0.45, $p < .001$). Consistent with hypothesis, trait positive affect at the between-person level (L2) was inversely associated with mean amount of drinks consumed during the sampling period (IRR = 0.77), representing a 23% change in average drinks for every 1 unit of change in trait PA (M = 3.33). Following the patterns exhibited at L1, at the between-person level trait negative affect and difficulty managing emotions were both unexpectedly not associated with the mean amount of drinks. None of the affect-related variables were significantly correlated with each other or gender at L2 ($ps > .11$).

Table 2 Multilevel structural model of direct effects of affect-related variables on nighttime alcohol use

Variable	*b*	IRR	SE	*p* value
Within-person (L1)				
Day negative affect	0.11	1.12	0.07	.116
Day positive affect	0.23	1.26	0.06	< .001
Day difficulty managing emotions	−0.08	0.92	0.09	.389
Monday	−0.38	0.68	0.23	.091
Tuesday	0.01	1.01	0.23	.980
Wednesday	0.41	1.51	0.22	.072
Thursday	0.73	2.08	0.20	< .001
Friday	1.36	3.90	0.22	< .001
Saturday	1.28	3.60	0.22	< .001
Elapsed date	− 0.08	0.92	0.06	.151
Between-person (L2)				
Trait negative affect	− 0.05	0.95	0.10	.608
Trait positive affect	− 0.26	0.77	0.09	.005
Trait difficulty managing emotions	0.08	1.08	0.13	.533
Gender	0.72	2.05	0.19	< .001

N = 92. Level 1 observations = 1709 person-days. Unstandardized coefficients. Gender (men = 1, women = 0). The test for orthogonal day of the week indicators represent that day's effect compared with the reference day, Sunday. Day of the week and elapsed day also had direct paths to the affect-related variables at level 1 but were but were omitted for clarity. At L1, the residuals of the affect variables were allowed to covary. At L2, gender and the affect variables were allowed to covary.

Indirect effects of affect-related variables though daytime attentional bias

To test the hypothesized mediation effects of daytime AAB, a multilevel structural mediation model (Preacher et al. 2010) was tested where daytime NA, PA, and difficulty managing emotions all had direct paths to daytime AAB, which, in turn, had a direct path to nighttime alcohol consumption. At level 1, six orthogonal day of the week indicators and elapsed days were included as exogenous covariates with direct paths to all endogenous variables (e.g., PA and alcohol consumption). The residuals of the affect-related variables were allowed to covary. At level 2, gender was included as an exogenous covariate with direct paths to attentional bias and alcohol consumption and correlated with the affect-related variables. All affect-related variables were allowed to covary with each other at level 2. Alcohol consumption was designated as having a negative binomial distribution. Prior to testing the indirect effects, we tested for additional direct effects of the affect-related variables on alcohol consumption to determine if the affective variables exhibit associations with the outcome that was not mediated by AAB. Direct paths from PA to alcohol consumption at both the between- and within-person levels were added. These were a significant improvement in the model, with the results favoring the revised model (AIC = 20,868.804, BIC = 21,266.191) over the base model (AIC = 20,877.836, BIC = 21,264.051) $\Delta\ \chi^2 (2) = 437.26, p < .001$, and thus were retained. Next direct paths from NA to alcohol consumption at both the between and within-person levels were added. This did not result in a significant improvement (AIC = 20,853.091, BIC = 21,255.922) $\Delta\ \chi^2\ (2) = 3.47,\ p = .176$ and was dropped from the model. Lastly, direct paths from difficulty managing emotions at both levels were added but did not result in significant additions to the model (AIC = 20,862.517, BIC = 21,265.368) $\Delta\ \chi^2\ (2) = 2.07,\ p = .355$ and were subsequently removed.

Results from this model (see Fig. 1) indicated that at the within-person level (daily-level; L1), daytime PA exhibited a significant positive direct effect on daytime AAB (IRR = 1.12) and nighttime alcohol consumption (IRR = 1.22). This latter effect translates to 22% increase in nighttime alcohol consumptions for every 1 unit increase in daytime PA. However, contrary to hypothesis, daytime NA and difficulty managing emotions were both not related to daytime AAB at the within-person level. Similarly, daytime AAB did not exhibit a direct effect on nighttime alcohol consumption at L1. At L2, trait PA exhibited an inverse direct effect on trait daytime AAB and a marginal inverse relationship with the mean amount of alcohol consumed during the sampling period ($p = .103$). There was a direct effect of male gender on alcohol

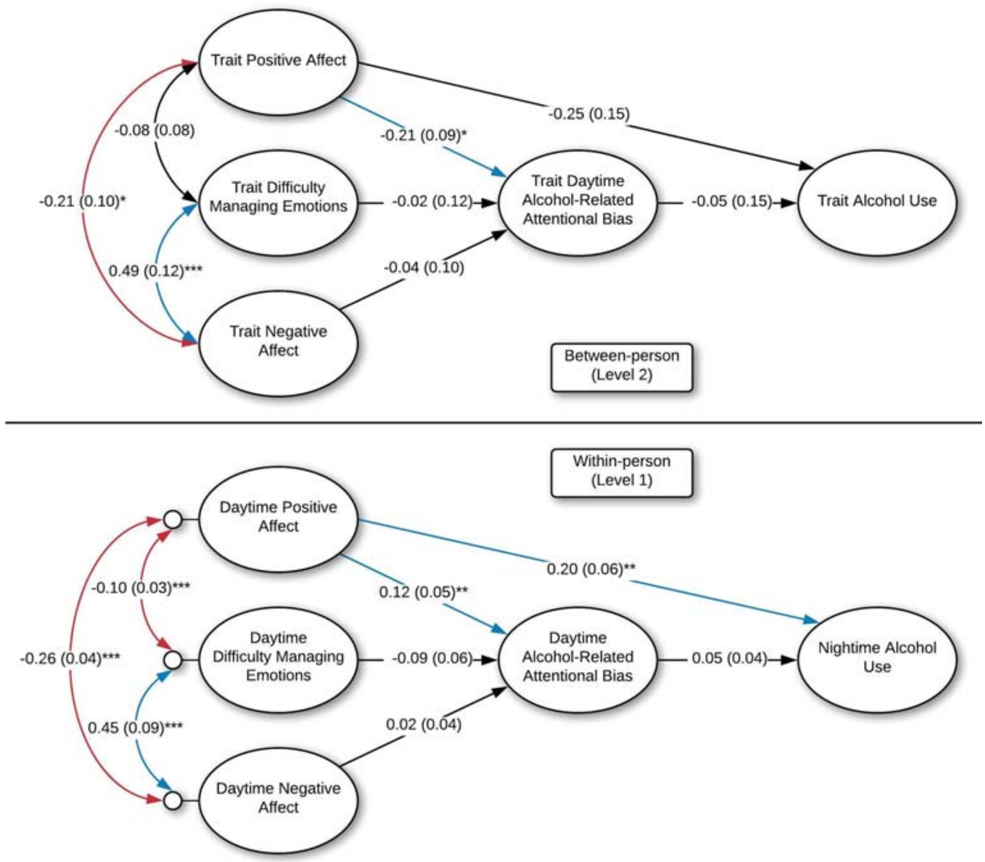

Fig. 1 Daytime AAB model of within- and between-person effects. Note. Unstandardized coefficients. Standard errors are in parentheses. Significant negative paths are presented in red and significant positive paths are presented in blue. AIC = 20,868.804, BIC = 21,266.191. Affect and difficulty managing emotions reflect ratings during the daytime. Alcohol use reflects number of drinks during the nighttime. Level 2 note. $N = 92$. "Trait" signifies dispositional characteristics. The between-person variable gender was included as a covariate and allowed to covary with affect, difficulty managing emotions, and alcohol-related attention bias but was omitted for clarity. Level 1 note. $N = 1709$ person-days. "State" refers to factors varying within-person across time. Within-person day of the week and elapsed day were included as covariates with paths to affect, difficulty managing emotions, alcohol-related attention bias, and nighttime alcohol use but were omitted for clarity. $*p < .05$, $**p < .01$, $***p < .001$

consumption ($b = 0.58$, IRR = 1.79, $p < .001$). Unexpectedly, there were no other significant direct effects at the between-person level. The indirect effects (see Table 3) were determined by testing the significance of the cross-products of coefficients. Inconsistent with hypothesis, there were no significant indirect effects of the affect-related variables on alcohol consumption via daytime AAB at either the within- or between-person level. Instead, daytime PA displayed a significant total effect on nighttime alcohol consumption at the within-person level and a marginal total effect at the between-person level.

Indirect effects of affect-related variables though nighttime attentional bias

To test the potential mediation effects of nighttime AAB, another multilevel structural mediation model (Preacher et al. 2010) was tested where lagged daytime NA, PA, difficulty managing emotions, and AAB all had direct paths to nighttime AAB, which, in turn, had a direct path to nighttime alcohol consumption. At level 1, six orthogonal day of the week indicators and elapsed days were included as exogenous covariates with direct paths to all endogenous variables (e.g., PA and alcohol consumption). The residuals of the daytime affect-related variables and daytime AAB were allowed to covary. At level 2, gender was included as an exogenous covariate with direct paths to nighttime AAB and alcohol consumption. Gender, affect-related variables, and daytime AAB were allowed to covary with each other at level 2. Alcohol consumption was designated as having a negative binomial distribution.

Results from this model (see Fig. 2)[1] indicated that at L1, daytime PA exhibited a significant positive direct effect on nighttime AAB (IRR = 1.09) and nighttime alcohol consumption (IRR = 1.20). In terms of drinking,

[1] We also estimated a simplified alternative model where the nighttime AAB and drinking were reversed in order, such that drinking was the mediator and nighttime AAB the final outcome. In this model, the association between nighttime drinking and nighttime AAB remained significant (b = 0.05, p = .003).

Table 3 Indirect and total effects for affect-related variables predicting nighttime alcohol use

Variables/Path	*b*	SE	*p* value
Daytime alcohol-related attention bias model			
Within-person indirect effects			
NA → daytime AAB → alcohol use	0.001	0.002	.630
PA → daytime AAB → alcohol use	0.005	0.005	.333
DME → daytime AAB → alcohol use	− 0.004	0.005	.396
Within-person total effects			
PA → alcohol use	0.207	0.060	.001
Between-person indirect effects			
NA → daytime AAB → alcohol use	0.002	0.002	.815
PA → daytime AAB → alcohol use	0.010	0.005	.766
DME → daytime AAB → alcohol use	0.001	0.005	.904
Between-person total effects			
PA → alcohol use	−0.236	0.140	.094
Nighttime Alcohol-Related Attention Bias Model			
Within-person indirect effects			
NA → nighttime AAB → alcohol use	− 0.005	0.003	.161
PA → nighttime AAB → alcohol use	0.008	0.005	.088
DME → nighttime AAB → alcohol use	0.000	0.004	.982
Within-person total effects			
PA → alcohol use	0.190	0.065	.004
Between-person indirect effects			
NA → nighttime AAB → alcohol use	0.002	0.015	.815
PA → nighttime AAB → alcohol use	0.034	0.026	.766
DME → nighttime AAB → alcohol use	− 0.032	0.028	.904
Between-person total effects			
PA → alcohol use	− 0.311	0.089	.000

$N = 92$. Level 1 observations = 1709 person-days. *NA*, negative affect; *PA*, positive affect; *DME*, difficulty managing emotions

this reflects an increase of 20% for each 1 unit increase in daytime PA. As expected, daytime AAB was positively associated with nighttime AAB. However, contrary to hypothesis, neither daytime NA nor difficulty managing emotions exhibited significant associations with nighttime AAB at the within-person level. Nighttime AAB exhibited a direct effect on nighttime alcohol consumption at L1 (IRR = 1.11). That indicates that a 1 unit concurrent increase in nighttime AAB was associated with a corresponding 11% increase in nighttime alcohol consumption. At L2, trait PA exhibited an inverse direct effect on both trait nighttime AAB (IRR = 0.87), and the mean amount of alcohol consumed during the sampling period (IRR = 0.71). This latter effect on drinking translates to a 29% change in average alcohol consumption for every 1 unit change in trait PA. Trait daytime AAB and difficulty managing emotions both exhibited positive direct effects on nighttime AAB. There was also a direct effect of male gender on alcohol consumption ($b = 0.90$, IRR = 2.46, $p < .001$). The indirect effects (see Table 3) were determined by testing the significance of the cross-products of coefficients. Inconsistent with hypothesis, there were no significant indirect effects of the affect-related variables on alcohol consumption via AAB at either the within- or between-person level. However, at the within-person level, daytime PA displayed a trend-level indirect effect on nighttime alcohol consumption via nighttime AAB ($b = 0.01$, $p < .088$). Daytime PA displayed a significant total effect on nighttime alcohol consumption at the within-person and between-person levels.

Discussion

The current study sought to clarify mixed findings observed in the negative reinforcement drinking literature by using a newly developed measure of state-based affect dysregulation to test if within-person changes in level of perceived difficulty of managing emotional distress were significant predictors of alcohol use, over and above levels negative and positive affect. What's more, this study used advances in mobile technology to assess state-based changes in AABs and test if these changes mediate the affect-related variables on alcohol use. Multilevel structural equation modeling was used to test these hypotheses about the relative contributions of within- and between-person affective constructs on AABs and alcohol consumption. Neither difficultly managing emotions nor NA had significant effects on drinking in the model. Yet, difficulty managing emotions displayed a significant positive association with nighttime AABs at the between-person level, as hypothesized. Similarly, PA exhibited the expected associations with both AABs and drinking. AABs showed significant within-person variance. Daytime AAB was not prospectively associated with subsequent nighttime drinking, but nighttime AAB was concurrently associated with nighttime alcohol use. In the following sections, the findings are discussed with respect to the theoretical rationale that formed the hypotheses.

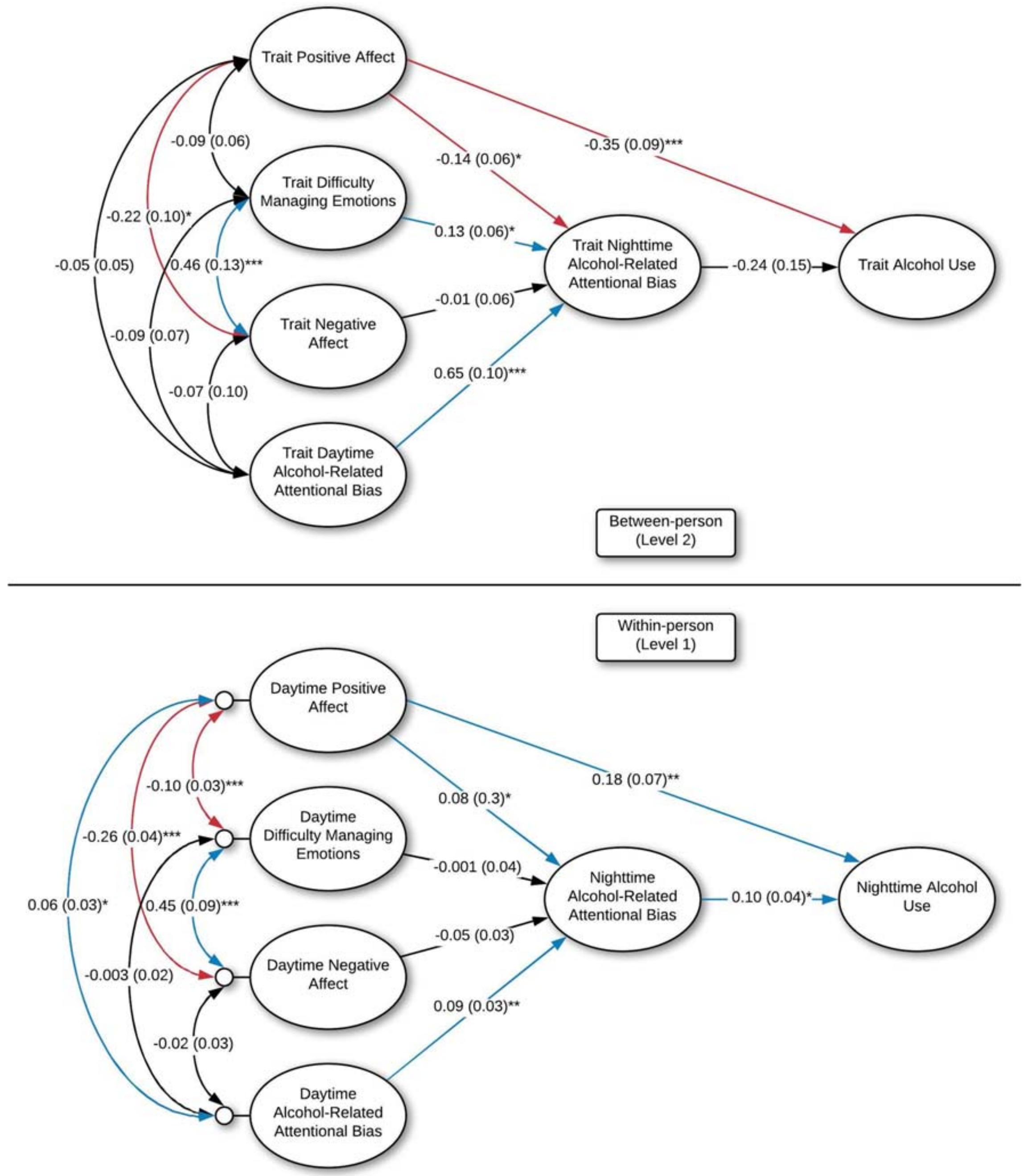

Fig. 2 Nighttime AAB model of within- and between-person effects. Note. Unstandardized coefficients. Standard errors are in parentheses. Significant negative paths are presented in red and significant positive paths are presented in blue. AIC = 25,765.181, BIC = 26,265.998. Affect and difficulty managing emotions reflect ratings during the daytime. Alcohol use reflects number of drinks during the nighttime. Level 2 note. $N = 92$. "Trait" signifies dispositional characteristics. The between-person variable gender was included as a covariate and allowed to covary with affect, difficulty managing emotions, and alcohol-related attention bias but was omitted for clarity. Level 1 note. $N = 1709$ person-days. "State" refers to factors varying within-person across time within-person day of the week and elapsed day were included as covariates with paths to affect, difficulty managing emotions, alcohol-related attention bias, and nighttime alcohol use but were omitted for clarity. *$p < .05$, **$p < .01$, ***$p < .001$

Negative reinforcement drinking

At their core, negative reinforcement models of alcohol use suggest that the experience of heightened negative affect during the day has implications for individual drinking decisions and level of use later that night. However, in the current study, within-person (i.e., state) negative affect during the day was not associated with heavier drinking later that night. This finding is consistent with previous research showing that, relative to positive affect, negative affectivity has historically exhibited weaker within-person associations with drinking (Kassel and Veilleux 2010; Wray et al. 2014). Similarly, at the between-person level (i.e., trait), dispositional NA was not related to greater levels of alcohol use. This too is in line with between-person studies that show that trait NA often exhibits weak or insignificant associations with drinking among young adults (Mezquita et al. 2010; Simons et al. 2005a). Taken together, these findings highlight that while there is strong theoretical rationale for the hypothesis that NA and drinking should be linked at the state level and that individuals with higher dispositional NA should be at increased risk for higher rates of alcohol use, the empirical support remains mixed.

To address the lack of clarity in the NA-alcohol use associations, we included a state-based measure of perceived difficulty managing emotions. The rationale behind this is that heightened levels of NA are but one potential sign of dysregulated affect and they may or may not actually prompt efforts to consciously regulate it, depending on other important contextual factors such as situational demands and features of the eliciting stimuli (Aldao and Tull 2015). Thus, even though a person may be experiencing high levels of NA, it may not be until their experience of NA exceeds their ability to manage it that substance seeking ensues. However, like NA, within-person (L1) increases in difficulty managing emotions during the day did not significantly predict increases in drinking behavior that night. Likewise, trait (L2) difficulty managing emotions was not associated with greater overall levels of alcohol use. The null findings related to NA and difficulty managing emotions could be used as evidence to suggest that young adult drinking is not associated with negative reinforcement processes. Yet, this conclusion seems premature for several reasons.

First, previous research has shown that at both the within- and between-person levels the association between NA and drinking quantity is relatively modest and not as substantial as with problematic use (Armeli et al. 2008; Hussong 2007; Simons et al. 2014). While our approach had many strengths, the final sample had less than the anticipated number of observations from which to estimate the level 1 effects and a relatively small sample from which test the level 2 effects. This, coupled with the trend-level effect for NA at level 1 in the direct effects model, makes it is reasonable to suspect that the models were ultimately under powered to detect hypothesized NA effects. Second, when examining the within-person means for NA and difficulty managing emotions it becomes clear that there was a limited number of times when participants endorsed experiencing considerable distress and, because of this, the current sample does not provide a great opportunity to test if perceived difficulty managing emotions is a significant predictor of drinking behavior, above and beyond NA and PA. For example, research with samples experiencing higher levels of distress, such as PTSD symptoms in veterans, has found significant within-person associations with drinking (Gaher et al. 2014; Possemato et al. 2015; Simons et al. 2018). Third, negative reinforcement drinking is thought to be more prevalent in those with problematic drinking patterns (Colder et al. 2010; Merrill and Read 2010). While moderate drinking was an inclusion criterion for the study, many participants did not display problematic drinking patterns during the sampling period. In sum, NA and problems managing NA display weaker effects and the expected associations appear more often with problematic use, in times characterized by substantial distress, and less often in less experienced drinkers. Therefore, future studies would benefit from increasing the number of observations/sample size and/or testing these models in a more severe sample.

Positive reinforcement drinking

At the within-person level, positive affectivity during the day was associated with increased alcohol use later that night as expected. As hypothesized, dispositional PA was inversely related to drinking at the between-person level. These findings replicate previous research demonstrating that PA's association with alcohol use shift from positive at the within-person level to inverse at the between-person level (Simons et al. 2014) and is consistent with the broader literature on the protective effects of well-being on substance use and risk promoting effects of low PA (Colder and Chassin 1997; Wills et al. 1999). Moreover, this provides additional empirical support for the discordance of PA at the within- and between-person levels, with state positive affect predicting acute increases in drinking, whereas trait positive affect is inversely associated with alcohol involvement (Colder et al. 2010).

As reviewed earlier, using ESM or other daily process methods, multiple state assessments can be captured and aggregated across several time points to make reliable trait measures of complex phenomenon because it minimizes recall bias. A rich traditional of cross-sectional research has fostered the assumption that relationships between constructs should correspond across levels of analysis. Although many psychological theories of substance use are largely based on dynamically unfolding within-person processes (e.g., positive and negative reinforcement), the majority of research has used between-person designs (Colder et al. 2010; Curran and Bauer 2011). There has been a tacit assumption that between-person relationships mimic the within-person associations. These data are the latest addition to a small but growing literature that indicates that this is not a valid assumption and that, in the case of PA and alcohol use associations, the within- and between-person levels require decomposition and distinct theory-driven hypotheses.

Trait positive affectivity is a broad psychological construct that is comprised of several similar valences but distinct feeling states (Tugade et al. 2004; Watson and Clark 1999). As such, theories of positive affectivity argue that PA promotes a wide range of enduring changes in psychological functioning and behavioral outcomes (Fredrickson 2001). For example, higher levels of trait PA contribute to increased physical activity (Fredrickson and Branigan 2005); increased engagement in academic, occupational, and prosocial community pursuits (Lyubomirsky et al. 2005); and increased adaptive coping and resilience to life stressors (Folkman and Moskowitz 2000; Tugade and Fredrickson 2007). Meanwhile, low levels of trait PA are associated with a series of deleterious health consequences, such as increased risk for poor physical health and chronic pain (Pettit et al. 2001; Zautra et al. 2005); anxiety and depression (Durbin et al. 2005; Genĉöz 2002); and use of poor coping strategies (e.g., avoidance and isolation; Campos et al. 2004). Thus, it makes sense that dispositional PA would be inversely associated with risky alcohol involvement.

In contrast, situation-specific acute changes in PA can give rise to appetitive behavior even if they are potentially incongruent with a person's characteristic affect level (Chiu et al. 2014; Cyders and Smith 2008) and alcohol is often an integral part of celebrated, positive social events (Neighbors et al. 2011). As noted in previous research (Simons et al. 2014), the within-person effects of PA on subsequent drinking may reflect, at least in part, anticipating a night of heavy drinking. In the current study, the effects of PA were significant while controlling for day of the week, which is associated with cyclical pattern of drinking exhibited by college students (Armeli et al. 2008). That being said, the relationship between PA and alcohol use may ultimately be a reciprocal one where positive emotion promotes increased drinking and that drinking behavior, in turn, promotes increased positive emotions. In sum, these data suggest that instances of increased drinking are predominantly associated with increased positive affect, whereas people who experience greater overall positive affect typically drink less. Interestingly, this pattern of associations was not exclusive to PA's relationship with drinking as PA exhibited effects on alcohol-related attentional biases in ways that mirrored that of drinking.

Alcohol-related attentional bias

Results from the MSEM analyses suggest a nuanced predictive relationship between AAB and drinking, such that lagged daytime AAB did not exhibit significant associations with nighttime drinking at either the within- or between-person levels; however, on days where concurrent nighttime AAB increased, participants consumed more alcohol that night. This aligns with the time course of lab-based paradigms that experimentally manipulate changes in AAB designed to prompt corresponding changes in drinking (Field et al. 2007; Field and Eastwood 2005). In these protocols, alterations to AABs precede alcohol consumption by only a short period of time, typically minutes. Coupled with the results found here, this may suggest that increases in AABs may only confer risk on individual acts of drinking for a relatively short period of time (e.g., minutes or hours). Alternatively, the concurrent nighttime AAB and drinking association may reflect a bidirectional relationship between AAB and drinking. Experimental alcohol administration research in this area indicates that acute alcohol use induces temporary dose-dependent *reductions* in AAB among heavy drinkers and then AAB returns as blood alcohol concentration decreases (Monem and Fillmore 2019; Roberts and Fillmore 2015; Weafer and Fillmore 2013). However, given that AAB and drinking were concurrently assessed, the temporal ordering of these variables is difficult to ascertain. More work needs to be done to clarify the directionality of this pattern at the event-level and characterize this potential feedback loop. Future research would benefit from user-initiated drink reports before and after each standard drink during a use episode to further characterize the exact timing.

As hypothesized, AABs exhibited substantial within-person variance, with 78–82% of the total variance observed at the within-person level. This is in line with contemporary research and theory that contends the majority of the variance in attentional biases that lie at the within-person level, rather than at the between-person level (Christiansen et al. 2015; Zvielli et al. 2014). Additionally, PA exhibited significant associations with both daytime and nighttime AABs at both the within- and between-person levels that mirror the associations between PA and alcohol consumption. That is, at the within-person level, daytime PA was positively related to both daytime and nighttime AAB while and trait PA was inversely associated with both trait daytime and nighttime AAB at the between-person level. This pattern suggests construct validity and is consistent with research that indicates that attentional biases to substance-related cues are expressed in shifting, phasic bursts and amenable to fluctuating appetitive states (Christiansen et al. 2015; Marhe et al. 2013). Furthermore, daytime PA exhibited a trend-level ($p = .088$) within-person indirect effect on alcohol consumption through changes in nighttime AAB. While non-significant, it does provide modest convergent validity for attentional bias as a variable linked to mood's association with alcohol consumption. Despite these interesting findings, AABs were not associated with NA or difficulty managing emotions at either the within- or between-person level, nor did they mediate the relationship between these variables and drinking at either level. The lone exception to this was positive association between difficulty managing emotions and nighttime AAB at the between-person level. While unexpected, these findings are not entirely surprising given the overall pattern of results (e.g., low amounts of distress). Instead, our findings are consistent with a sample where drinking and attentional biases are characterized by positive reinforcement processes (e.g., PA) rather than coping with distress.

Lastly, our TL-BS-based measure of AAB exhibited modest internal reliability. This is a noteworthy result given that the poor reliability of AAB measures has long been a topic of discussion among researchers in the area (e.g., Ataya et al. 2012; Emery and Simons 2015; Jones et al. 2018). This suggests that TL-BS-based measures have the potential to be more internally reliable than mean-based measure (Zvielli et al. 2014). Despite this, some newer research has suggested that TL-BSs should be used with caution because computer simulations show that they have the potential to be influenced by overall RT variability. Thus, the results here should be interpreted with caution. To investigate if our data exhibit a similar sensitivity, we calculated measures of overall RT variability for daytime and nighttime trials respectively and examined their relationship with daytime and nighttime AAB metrics derived from TL-BSs. We found that daytime RT variance and daytime AAB ($r = .20$) as well as nighttime RT variance and nighttime AAB ($r = .21$) were both weakly associated.

Strengths and limitations

Several limitations of the current study should be noted. First, the sample for this study was primarily composed of white college students from a small Midwest university; thus, generalization to other populations should be done with caution. Our analytic approach was rigorous, and we controlled for contextual factors of import to longitudinal data; however, MSEM does not allow for the incorporation of residual autocorrelations which is a potential limitation. Also, the application used to administer the ESM protocol experienced a series of technical difficulties that contributed to a lower number of observations and potentially decreased power. As mentioned previously, there was a modest association between compliance and baseline drinking levels suggesting that heavier drinkers at baseline experienced greater difficulty adhering to the ESM protocol.

While the temporal ordering is a significant strength compared with cross-sectional research, it does not equate to causality as there is not an experimental manipulation. However, as with all research, there is a tradeoff between experimenter control and external validity. Thus, the current methodology capitalized on external validity by examining effects in context with temporal precedence between many variables of interest. However, despite this strength, not all of our relationships were lagged. For example, nighttime AAB and nighttime alcohol consumption were assessed concurrently which does not allow us to determine the temporal relationship. This is a limitation of the current analyses. Another strength is that we administered reaction time-based cognitive tasks on a mobile device, though this approach is not without its drawbacks. Deploying reaction-time measures in the natural environment can introduce noise to the data not present when under tight experimental control in the lab. To mitigate this, participants identified signals that were interrupted for any reason (e.g., phone call and person talking to them) and these signals were subsequently removed from the calculation of AABs. However, the potential exists that there were subtle distractions in the environment not identified by participants, potentially interfering with estimates of AABs leading to decreased magnitude in AAB associations with variables of interest. These concerns are somewhat attenuated by our rigorous outlier detection protocol and the modest construct validity observed for AABs. Considering these challenges, it is not surprising that very few studies have assessed attentional bias in the natural environment using ESM. Our findings are in line with these studies and suggest that it is feasible to administer reaction-time-based measures of attentional bias on mobile electronic devices (Waters and Li 2008). However, only one previous study examined the effects of alcohol-related attentional biases (Szeto et al. 2019) and many of them were conducted with treatment seeking clinical samples where participants were not permitted to take the device outside of the treatment facility (Marhe et al. 2013; Waters et al. 2012). Thus, this represents an important extension in feasibility of administering RT-based cognitive tasks in the participant's natural environment. Lastly, this study represents a first exploration of the State Difficulty in Emotion Regulation Scale (S-DERS) performance longitudinally using ESM. We found that S-DERS had good internal consistency at both the within- and between-persons levels and exhibited reasonable discriminant validity from negative affect with ~ 36% shared variance. This suggests that this measure is appropriate for use in daily process methodology.

Summary

The current study examined the role of affect, difficulty managing emotional distress, attentional bias, and young adult alcohol use in an ecological framework. Results showed that neither negative affect nor difficult managing emotions had significant effects on alcohol use or alcohol-related attentional bias at the within-person level. However, positive affect exhibited the expected associations with both attentional biases and drinking. Alcohol-related attentional biases showed significant within-person variance and nighttime, but not daytime, AAB was significantly related to nighttime drinking. Our findings replicate previous research showing that daily increases in positive arousal were associated with increased drinking, while higher levels of trait positive affect were associated with a decrease alcohol consumption and extend this work by showing that positive affect exhibits associations with attentional biases in a pattern that mirrors its relationship with drinking. These results suggest that day-to-day fluctuations of positive emotional arousal in young adult drinkers are associated with changes in cognitive processing that result in increased attention toward, and salience of, alcohol-related cues in the environment. Thus, even for the relatively moderate drinkers in this sample, feelings of excitement, happiness, and joy may result in a perceived environmental context filled with stimuli promoting drinking. These patterns of results exemplify how trait affect, because of its wide-reaching effects on psychosocial functioning, can exhibit associations with behavior that are discordant with influence of emotion at the within-person level. In sum, our findings are consistent with research suggesting that positive emotional experiences are an important factor in young adult alcohol involvement (e.g., Howard et al. 2015; Simons et al. 2014) and we extend this work by showing that positive affect is associated with systematic changes in incentive salience of alcohol-related cues that mirror positive affect's relationship with drinking.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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