

The Pennsylvania State University

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**THE ROLE OF NEGATIVE AFFECT AND SOCIAL EXPERIENCES PREDICTING
CHANGES IN DAILY CRAVING FOR INDIVIDUALS IN RESIDENTIAL TREATMENT
FOR OPIOID USE DISORDERS**

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Kyler Scott Knapp

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The thesis of Kyler Scott Knapp was reviewed and approved* by the following:

H. Harrington Cleveland III
Professor of Human Development and Family Studies
Thesis Adviser

Timothy R. Brick
Assistant Professor of Human Development and Family Studies

Lesley A. Ross
Associate Professor of Human Development and Family Studies
Professor-in-Charge of the Graduate Program

*Signatures are on file in the Graduate School

ABSTRACT

Drug craving is one of the strongest predictors of relapse among individuals addicted to various substances, including opioids. There is a lack of research exploring within-person transactions between individual and environmental factors associated with craving among individuals in treatment for opioid use disorders. The current ecological momentary assessment (EMA) study aimed to partially address this gap by examining associations of daily craving with negative affect (NA), positive social experiences (PSE), and negative social experiences (NSE). Participants at a residential drug and alcohol treatment facility completed smartphone-based surveys 4 times per day for 12 consecutive days. Results revealed that craving was higher on days when negative affect was higher than usual, as well as on days when individuals experienced more negative social interactions than usual. Further, there was a stronger within-day association between negative affect and craving on days with fewer positive social interactions compared to days with more positive interactions than usual. These findings advance understanding of socioemotional experiences within treatment environments and highlight the moderating role of ecological characteristics on within-person links between negative affect and craving.

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Chapter 1

Introduction

Addiction is a chronic relapsing condition. One of the primary predictors of relapse is craving (Weiss, 2005). A growing body of ecological momentary assessment (EMA) and daily diary literature examines how individual treatment experiences, including craving, unfold in real time to better understand how and when these experiences may influence relapse risk. However, few studies have examined how intraindividual phenomena interact with daily social experiences to contribute to craving (and thus enhance relapse risk). This study will use EMA to explore how negative affect, social experiences, and craving interact in individuals receiving treatment for opioid use disorders. First, we outline the theoretical framework used to guide the analyses and describe how it fits into a patient-centered approach to understanding addiction processes. Next, we review the literature on craving, negative affect, negative social experiences, and positive social experiences due to their demonstrated importance during treatment and recovery. Finally, we describe the specifics of the current study's analytic approach and set out our research questions.

Theoretical Framework

The current study is guided by the dynamic model of Relapse Prevention (RP) originally developed by Marlatt (Marlatt & Gordon, 1985) and updated by Witkiewitz and Marlatt (Hendershot, Witkiewitz, George, & Marlatt, 2011; Witkiewitz & Marlatt, 2004). According to this framework, relapses are caused by high-risk situations, which are defined broadly as any context that confers vulnerability. These high-risk situations include contextual precursors, such

as encounters with people or places that trigger memories of past drug use, as well as internal cues, such as emotional or cognitive states. The situations that confer risk vary across individuals, but they also vary within the same individual over time (Hendershot et al., 2011). Further, this model posits that recovery is a dynamic and complex process that includes both between-person (i.e., tonic) and within-person (i.e., phasic) influences on relapse risk. Between-person influences include more stable processes, such as family histories of substance abuse and physical withdrawal. Within-person influences include more transient processes, such as craving and affective state. Thus, according to this model, between-person processes help determine *who* is vulnerable to relapse while within-person processes help determine *when* and *how* relapse might occur (Hendershot et al., 2011). Importantly, there may also be processes happening at a variety of other timescales in between, but the current study will only consider these two levels.

In summary, a key component of the Relapse Prevention model is understanding the between- and within-person interactions among internal and external factors associated with relapse. We suggest that it is necessary to consider that contextual influences during treatment not only consist of experiences that may confer risk, but also those that may be protective. This perspective is consistent with two extensions to the model, both of which more fully incorporate social variables as modifiers of intraindividual processes (e.g., self-regulation) among individuals with SUDs (Hunter-Reel, Mccrady, & Hildebrandt, 2009; Roos & Witkiewitz, 2017). The current study employs an EMA design to explore the dynamic intraindividual interactions between external and internal contexts that are proposed by these models among individuals in treatment for opioid dependence.

Patient-Centered Approach

A majority of prior research in the field of substance use disorder (SUD) treatment considers differences in treatment experiences and outcomes between people. These approaches fail to capture the day-to-day and moment-to-moment variability in treatment experiences as they unfold within single individuals. A small but growing number of studies have used experience sampling approaches, such as ecological momentary assessment (EMA), to assess intraindividual associations among individual and environmental factors associated with relapse risk. EMA is well-suited for studying dynamic and complex phenomena in their natural environment, such as craving (Zheng, Cleveland, Molenaar, & Harris, 2015). Since craving is a momentary experience, the repeated measurements produced by EMA provide advantages over traditional methods by limiting retrospective recall bias and producing data that is more ecologically valid (Kjellsson, Clarke, & Gerdtham, 2014; Smyth, Juth, Ma, & Sliwinski, 2017), while also capturing within-day variability and temporal dynamics (Shiyko & Ram, 2011; Serre, Fatseas, Swendsen, & Auriacombe, 2015).

EMA has been repeatedly demonstrated as a valid and feasible approach for studying tobacco and alcohol addiction, yet no known studies exist among a sample of addicts in residential treatment with opioids as the primary substance of abuse (Serre et al., 2015). Despite the growing concern over opioid use, there is a lack of research using EMA methodology to investigate the daily experiences of opioid treatment and recovery. In the current study, we focus on craving, negative affect, and positive and negative social experiences within the residential setting.

Craving

Subjective craving is defined as the unwanted urge to use a drug (Serre et al., 2015). Research has shown that craving predicts use of all drugs of abuse, including tobacco (Catley, O'Connell, & Shiffman, 2000), alcohol (Litt, Cooney, & Morse, 2000), and opioids (Tsui, Anderson, Strong, & Stein, 2014). Craving is experienced during and after treatment and is one of the primary predictors of relapse (Weiss, 2005). In the last decade the link between craving and relapse has been well-supported by EMA studies across various substances and users at different stages of addiction (for a review, see Serre et al., 2015). For instance, craving strongly predicts substance use at the next assessment among patients currently in outpatient addiction treatment (Fatseas, Serre, Swendsen, & Auriacombe, 2018) and individuals who have undergone treatment in the past year (Scott, Dennis, & Gustafson, 2018). One study among individuals entering intensive outpatient treatment found that those who reported an increase in craving were 14 times more likely to relapse at the next assessment compared to those who did not report increased craving (Moore et al., 2014).

Research specific to certain substances of abuse has found that craving predicts subsequent use among alcohol, tobacco, and cannabis users (Serre, Fatseas, Denis, Swendsen, & Auriacombe, 2018). They did not find an effect for opiate users, but other research has found evidence of increased craving before and after relapse to opioids (Preston et al., 2018). Although there may be mixed results for craving's relationship to use of opioids that warrant further investigation, the body of research suggests craving may be a critical influence on relapse.

Negative Affect

Negative affect (NA) is a persistent indicator of withdrawal that has a strong association with substance use outcomes, including craving and relapse. NA has been defined as a negative emotional state in response to internal or external stimuli (Hussong, Jones, Stein, Baucom, & Boeding, 2011). Previous research has assessed the intra-individual association between affect on craving across various substances, with most EMA and daily diary studies generally finding a positive association (Serre et al., 2015). Higher negative affect significantly predicts same-day levels of craving and consumption among college students not seeking treatment for alcohol problems (Simons, Gaher, Oliver, Bush, & Palmer, 2005), as well as students in recovery from different SUDs (Cleveland & Harris, 2010). The association between NA and craving has also been found for patients beginning treatment for tobacco (Serre et al., 2018) and opioid (Huhn et al., 2016) addictions, as well as for a non-treatment seeking smokers (Bujarski et al., 2015).

Although there is strong evidence for this within-person relationship, there are likely differences both between- and within-person in the conditions under which NA is associated with craving. At the between-person level, individuals differ in their reactivity to stress and negative mood during post-withdrawal state from opiates (Koob & Le Moal, 2001). At the within-person level, some days may present experiences that intensify the association between affect and craving. It may be on these more difficult days that deviations from normal levels of NA lead to increased susceptibility to craving, such that days with higher-than-average NA are associated with craving above and beyond average levels. This possibility suggests that it may be important to examine within-person moderators of the NA-Craving relationship to determine on what days individuals are more or less reactive to NA, and more or less susceptible to craving as a result.

Social Experiences

Social experiences and how individuals react to them may also impact recovery outcomes and relapse risk. On the one hand, negative social interactions, such as interpersonal conflict and social stress, may increase individuals' risk for craving and/or relapse. Stressful social situations increase reports of craving for cocaine (Waldrop et al., 2010), alcohol (Clay et al., 2018), cannabis (Buckner, Zvolensky, Ecker, & Jeffries, 2016), and tobacco (Watson, Demarree, & Cohen, 2018). Perceived criticism is associated with relapse among opioid-dependent patients (Kadam, Sinha, Nimkar, Matcheswalla, & De Sousa, 2017). Additionally, negative family behaviors (e.g., withdrawing, not tolerating behavior) are associated with more drinking (McCrary, Hayaki, Epstein, & Hirsch, 2002), and stressful relationships with friends also predict poorer outcomes (Gordon & Zrull, 1991). Although most of these findings are based on laboratory studies, within-person data across multiple days has shown that negative social experiences are positively associated with same-day craving (Cleveland & Harris, 2010). These types of data help elucidate the daily experiences that can trigger craving and place individuals at heightened risk for relapse.

Research related to peer-based recovery services and 12-step modalities of reciprocal support, such as Alcoholics Anonymous, suggests that positive social support is also important to consider during the treatment and recovery process. The limited number of studies evaluating peer-based recovery services have found some evidence of effectiveness, including more cocaine and heroin abstinence (Bernstein et al., 2005), and significantly lower levels of alcohol use (Rowe et al., 2007). Similarly, research on Collegiate Recovery Programs (CRPs), which provide academic and social support to students in recovery, has found evidence of low relapse rates and high overall academic success (Cleveland, Harris, Baker, Herbert, & Dean, 2007; Harris, Baker, Kimball, & Shumway, 2007; Laudet, Harris, Kimball, Winters, & Moberg, 2014). Consistent

with the putative positive role of positive social experiences, attending and being involved in 12-step meetings have also been associated with improved long-term abstinence outcomes (Fiorentine & Hillhouse, 2000; Humphreys, Huebsch, Finney, & Moos, 1999; Kelly, Stout, & Slaymaker, 2013; Magura, 2007; Timko, Moos, Finney, & Lesar, 2000).

The underlying theme of the research summarized above, whether linked to a recovery program or not, is that social support predicts recovery success. Research in this area has elucidated several aspects of social support that relate to treatment outcomes (Hunter-Reel et al., 2009). The number of supportive relationships (Zywiak, Longabaugh, & Wirtz, 2002), the degree of support provided by the most supportive members of the network (Barber & Crisp, 1995), and the type of support offered (drug-specific vs. general support; Havassy, Hall, & Wasserman, 1991) all predict outcomes. The amount of social investment is also important, as those who are highly invested in others benefit from abstinence support while those with low investment may not (Longabaugh, Wirtz, Beattie, Noel, & Stout, 1995; Zywiak et al., 2002). Collectively, this work suggests that social support is a critical element of “recovery capital” that is important for initiating and sustaining recovery from substance use (Cloud & Granfield, 2008).

What is not yet well understood, however, is how social experiences and individuals’ emotional experiences combine to reduce or enhance relapse risk. Different aspects of the social environment could influence one another, such as socially supportive individuals replacing or buffering the negative influences of non-supportive individuals (Humphreys & Noke, 1997; Bond et al., 2003). Additionally, changes in social factors could interact with intraindividual processes, such as negative affect or craving. For example, negative social interactions may exacerbate NA and/or craving and put individuals at increased risk for relapse, while positive social support may mitigate this risk. Studies have found stronger associations between daily negative affect and drinking among those with lower social support (Hussong, Hicks, Levy, & Curran, 2001), and weaker relationships among individuals with positive social support (Hussong et al., 2011). Thus,

studies that consider how multiple internal and external factors interact may provide a unique perspective that elucidates the processes that put an individual at risk for relapse.

Chapter 2

The Present Study

The current study employs a 12-day EMA design to assess daily variation in craving from intraindividual variability in same-day negative affect (NA), negative social experiences (NSE), and positive social experiences (PSE) among individuals receiving treatment for opioid use disorders. This design will provide insight into how daily changes in internal and external contexts may place individuals at either heightened or reduced risk for craving. The primary goal is to investigate daily positive and negative social experiences as moderators of negative affect-related changes in daily craving. Investigating the interactions among affect and social experience when predicting craving will illuminate how daily linkages in one domain (such as between NA and craving) may vary based upon day-to-day changes in another domain (such as social experience). The secondary goal is to investigate daily positive social experiences as a moderator of NSE-related changes in craving to determine whether there is a relationship between NSE and craving that varies depending on levels of PSE. This type of analysis is an important step toward identifying when experiences such as NA or NSE can lead to craving (and thus increase relapse risk), as well as whether PSE acts as a buffer within this population. Increasing understanding of how social interactions and affect may contribute to variation in craving would subsequently aid the development of better treatments, such as mobile just-in-time adaptive interventions, by elucidating potential targets of intervention and guiding the timing of intervention delivery.

The specific research questions were:

1. Do intraindividual fluctuations in daily NA, PSE, and NSE predict variation in same-day craving? Are there interindividual differences in these intraindividual associations?
2. Are intraindividual associations between NA and craving moderated by daily positive and negative social experiences (PSE and NSE)?

3. Are intraindividual associations between NSE and craving moderated by daily PSE?

Chapter 3

Methods

Participants

Participants were 73 patients (77% male), age 19 to 61 ($M_{\text{age}}=30.10$, $SD_{\text{age}}=10.13$) at a residential drug and alcohol treatment facility that met criteria for prescription opioid dependence as determined by the Structured Clinical Interview for DSM-IV-TR (SCID; First, 2005), and Form-90D (Westerberg, Tonigan, & Miller, 1998), for whom opioids were the primary drugs of abuse, and who had completed medically assisted withdrawal from prescription opioids in the last 10-14 days. Other inclusion criteria included being at least age 18 years, scheduled to stay in residential treatment for at least 30 days, and willingness to comply with the research protocol. Patients were excluded from participation if they had any history of serious mental illness, traumatic brain injury, or intravenous drug use, as well as any current use of opiate agonists (methadone or buprenorphine) or antagonist (Naltrexone).

Patients were prescreened to identify participants that met these criteria who were then invited to take part in the study. All participants provided written informed consent after the study protocol was fully explained to them. Demographic information on this sample, including information about psychiatric comorbidity, addiction history, and concurrent medication use of the participants, has been published elsewhere (Huhn et al., 2016; Lydon-Staley et al., 2017).

Procedure

Participants were invited to take a smartphone-based survey 4 times per day for up to 12 consecutive days. A preset alarm notified participants that a survey was ready to be taken at early

morning, late morning, mid-afternoon, and evening times that did not conflict with their treatment programs. The surveys took approximately 2-3 minutes each to complete. If participants did not choose to take the survey after the first notification, they were given opportunities every 15 minutes for up to one hour, after which the survey was closed until the next measurement occasion. Research staff encouraged survey participation by using brief in-person meetings to answer questions and manage technical difficulties. For the current analysis, data were available for 594 days nested within 71 persons. Participants provided an average of 9.07 (Range = 4 - 14) days each. All study procedures were approved by the Pennsylvania State University College of Medicine Internal Review Board.

Measures

Craving

Craving was measured four times per day for up to 12 consecutive days with two items that assessed craving frequency and intensity on a continuous touchpoint scale (slider-type) with anchors at each end (0=No craving and 100=Very frequent/intense). Specifically, the items were, “Since last data entry [Since waking], how frequent were your drug cravings?” and, “Since last data entry [Since waking], how intense were your drug cravings?”. Correlations between the frequency and intensity scores ranged from .74 to .76 across the day. The product of the frequency and intensity of drug craving was used to create a *craving volume* score for each individual at each time point. An average craving volume score was created for each participant for each day of the study by averaging across the four assessments. The measure provided reliable assessment of within-person change, $R_c = 0.86$ (as per the generalizability theory approach for intensive repeated measures data, see Bolger & Laurenceau, 2013).

Negative Affect

Negative affect (NA) was measured four times per day for up to 12 consecutive days using eight items from the PA-NA Scales (Watson, Clark, & Tellegen, 1988) on a continuous touchpoint scale with anchors at each end (0 = Not at all and 100 = Very). The items took the form, “Since last data entry [Since waking], have you felt... “angry,” “irritable,” “lonely,” “sad,” “guilty,” “ashamed,” “anxious,” and “stressed”. A composite NA score was calculated for each participant for each day as the average of the eight responses across the day, $R_c = 0.80$. Additionally, a person-level variable for negative affect was created for each participant by calculating the arithmetic mean across each participant’s repeated measures.

Negative Social Experiences

Negative social experiences (NSE) were measured three times per day (late morning, mid-afternoon, and evening) with five binary (yes/no) items that were adapted from the Test of Negative Social Exchange (TENSE) scale (Ruehlman & Karoly, 1991). Example items include, “Since last data entry, did someone lose his/her temper with you?” and “Since last data entry, did someone get angry with you?”. The items were coded (1=yes, 0=no) and then summed across the three daily measurement occasions to create a count measure of negative social experiences for each participant for each day of the study with at least one completed measurement occasion, $R_c = 0.82$.

Positive Social Experiences

Positive social experiences (PSE) were measured three times per day (late morning, mid-afternoon, and evening) with five binary (yes/no) items modified from the TENSE scale.

Example items include, “Since last data entry, did someone compliment you?” and “Since last data entry, did someone show you that they cared about you?”. The items were coded (1=yes, 0=no) and summed across the three daily measurement occasions to create a count measure of positive social experiences for each participant for each day of the study with at least one completed measurement occasion, $R_c = 0.75$.

Chapter 4

Data Analysis

We examined within-person associations among daily negative affect, positive and negative social experiences, and craving using a multilevel modeling (MLM) framework that accommodated the nested nature of the data (repeated measures nested within persons; Bolger & Laurenceau, 2013; Raudenbush & Bryk, 2002).

Data Preprocessing

Per usual practice (Bolger & Laurenceau, 2013), the NA, PSE, and NSE variables were split into time-varying and time-invariant components. Person-level variables representing time-invariant or “trait” NA, PSE, and NSE were computed for each participant as the arithmetic mean of their repeated measures. Time-varying or “state” variables were computed for each individual on each day as the difference between the observed score and the individual’s person-mean. Trait-level variables were grand-mean centered to represent between-person differences in NA, PSE, and NSE on average across the study period. Time was centered on Day 1 of the study.

Additionally, Tukey’s Ladder of Powers approach was applied to perform a power transformation on the outcome variable, daily craving, in order to correct for the positive skewness and avoid violating the assumption that residuals were normally distributed. This approach performs iterative Shapiro-Wilk tests to find the power transformation that makes the data fit the normal distribution as closely as possible. The lambda value that maximized the W statistic for the iterative Shapiro-Wilk tests was 0.275. A lag-1 variable for daily craving was then created and included in all models to control for the autoregressive effects of craving from day-

to-day, thus allowing us to examine the effects of NA, PSE, and NSE on the change in craving from one day to the next.

Multilevel Models

Correlational analyses were first conducted to test whether PSE and NSE were associated with each other or with average daily NA at the between-person level. Multilevel models were then fit to evaluate the effects of time-varying levels (i.e., within-person variation) of negative affect, negative social experiences, and positive social experiences on change in daily craving (i.e., controlling for yesterday's craving). First, the daily within-person effects of NA, PSE, and NSE were examined to assess whether daily fluctuations predicted variation in daily craving after controlling for craving from the previous day and usual "trait" levels of all three variables. Subsequent models were tested to assess whether there were interindividual differences in any intraindividual associations. Second, social experiences (PSE and NSE) were tested as moderators of NA-related changes in craving after controlling for craving from the previous day. Third, interaction effects between NSE and PSE were tested, controlling for yesterday's craving and same-day NA.

Models for the associations between NA, NSE, PSE, and same-day craving controlling for previous day's craving were constructed as:

Level 1:

$$Craving_{it} = \beta_{0i} + \beta_{1i}Craving_{it-1} + \beta_{2i}Day'sNA_{it} + \beta_{3i}Day'sPSE_{it} + \beta_{4i}Day'sNSE_{it} + \beta_{5i}Time_{it} + \epsilon_{it}$$

In the above equation, i indexed individuals and t indexed time points. $Craving_{it}$ is the reported craving for person i on day t ; β_{0i} indicates the expected level of craving on the first day of the study when all predictors are at their mean level for the typical individual; β_{1i} , β_{2i} , β_{3i} , and β_{4i} indicate within-person differences in craving associated with yesterday's craving, NA, PSE, and

NSE variables, respectively; B_{5i} indicates the effect of time in the study on craving in order to account for time as a third variable (see Bolger & Laurenceau, 2013); and e_{it} are day-specific residuals that were allowed to autocorrelate (AR1).

Person-specific intercepts and variance from the Level 1 model were specified at Level 2 as:

Level 2:

$$\beta_{0i} = \gamma_{00} + \gamma_{01}Age_i + \gamma_{02}Gender_i + \gamma_{03}UsualNA_i + \gamma_{04}UsualPSE_i + \gamma_{05}UsualNSE_i + \nu_{0i}$$

$$\beta_{1i} = \gamma_{10} + \nu_{1i}$$

In the above equations, the gamma (γ) coefficients represent between-person differences in individual effects. Models were tested with six between-person (Level 2) random effects: a random-intercept (ν_{0i}), five random slopes ($\nu_{1i}, \dots, \nu_{5i}$); and residual error terms (e.g., ϵ_{it}). The random intercept captures between-person variability in participants' average level of craving, whereas each random slope captures between-person variability in the strength of the relation between one predictor and daily craving. Additionally, age, gender, and usual levels of negative affect, positive social experiences, and negative social experiences were added as Level 2 predictors of the intercept to control for between-person differences in craving according to these person-level characteristics. The models were fit using the nlme package in R (Pinheiro, Bates, DebRoy, Sarkar, & Core Team, 2015) using maximum likelihood estimation, with incomplete data treated using missing at random assumptions. Table 2 reports the results from two models, one with main effect associations only and the other with the addition of interaction terms, but all results reported below are from the final model with the interaction terms included. Statistical significance was evaluated at $\alpha = 0.05$.

Chapter 5

Results

Results are presented in five sections, working first through the descriptive and correlational findings, then the findings addressing each of the three research questions, respectively, and finally the results of supplemental analyses run at the between-person level.

Descriptive and correlational analyses

Descriptive statistics summarizing the longitudinal data for all variables included in the analysis are presented in Table 1. On average, participants reported a raw mean daily craving of 11.15 ($SD = 18.28$) on a 0-100 scale. After the transformation of this variable following the procedure described above, the mean daily craving was 4.84 ($SD=3.34$). On average, participants reported a mean daily NA of 34.83 ($SD = 20.46$), a mean number of daily PSE of 5.04 ($SD = 4.48$), and a mean number of daily NSE of 1.10 ($SD = 2.08$). It is notable but expected that PSE are substantially higher than NSE, given the treatment context of the data collection.

Contemporaneous PSE and NSE were positively correlated [$r(1,874) = 0.25, p < .001$]. While PSE was unrelated to NA [$r(1,702) = 0.01, p = .73$] during the same day, NSE was significantly correlated with higher NA [$r(1,702) = 0.23, p < .001$] during the same day. The effect of time revealed a significant main effect of day of study on craving, such that craving decreased during the course of the study ($b = -0.12, p < .001$). A quadratic effect of time in addition to the linear effect of time was tested, but showed no significant association with craving. Only linear time was retained and included in all models for analysis.

Table 1: Descriptive statistics.

	1	2	3	4	5	6	<i>M</i>	<i>SD</i>	<i>ICC</i>
Baseline									
1. Age							30.10	10.13	----
2. Gender	-.32						0.77	0.43	----
Daily									
3. Craving	-.13	-.05					4.84	3.34	.68
4. Negative Affect	.05	-.09	.52	.40			34.83	20.46	.67
5. Positive social experiences	.15	-.05	.00	-.08	.01		5.04	4.48	.39
6. Negative social experiences	-.03	.02	.22	.16	.23	.25	1.10	2.08	.22

Research Question 1

The first research question was to investigate whether the daily within-person effects of NA, PSE, and NSE uniquely contributed to prediction of change in daily craving after controlling for previous day's craving and average NA, PSE, and NSE. Results are shown in Table 2.

Findings indicated that the within-person association between day's NA and craving was significant ($b = 0.05$; 95% CI = 0.04, 0.07). That is, on days when participants' NA was higher than usual, craving increased after controlling for yesterday's craving; average negative affect, PSE, and NSE; daily PSE and NSE; and day of study. Additionally, the within-person association between day's NSE and craving was significant ($b = 0.09$; 95% CI = 0.01, 0.17). That is, on days when participants had more NSE than usual, craving increased after controlling for yesterday's craving; average negative affect, PSE, and NSE; daily NA and PSE; and day of study. The within-person association between PSE and craving was not significant ($b = 0.03$, *n.s.*). The fixed and random effects of NA, PSE, and NSE, along with age, gender, and usual NA, PSE, and NSE together explained 5.91% of the variance in craving. A likelihood-ratio test was used to perform model comparisons between models with and without random slopes for previous day's craving, NA, PSE, NSE, and day of study, and results revealed that a model with random slopes for

previous day's craving and NA fit the data significantly better than a model without these random slopes (likelihood-ratio estimate = 18.01; $p < .01$). These significant random effects indicate that there were interindividual differences in the autoregressive effects of craving, as well as in the intraindividual association between NA and craving.

Table 2: Results of multilevel models examining associations among negative affect, negative social experiences, and positive social experiences with change in daily craving.

Fixed Effects	Model 1		Model 2	
	Estimate	S.E.	Estimate	S.E.
Intercept	5.68*	0.92	5.66*	0.93
Linear slope	-0.06*	0.02	-0.06*	0.02
Age	-0.04*	0.02	-0.04	0.02
Gender	-0.35	0.47	-0.38	0.48
Mean NA	0.07*	0.01	0.07*	0.01
Mean PSE	-0.08	0.07	-0.09	0.07
Mean NSE	0.20	0.18	0.20	0.19
Day-level craving (lag-1)	0.23*	0.05	0.23*	0.05
Day-level NA	0.05*	0.01	0.05*	0.01
Day-level PSE	0.03	0.02	0.03	0.02
Day-level NSE	0.09*	0.04	0.09*	0.04
Day-level NA × PSE			-0.01*	0.002
Day-level NA × NSE			0.00	0.004
Day-level NSE × PSE			-0.01	0.012
Day-level NA × PSE × NSE			0.00	0.001
Random Effects	Estimate	95% CI	Estimate	95% CI
Intercept	1.98	1.49-2.62	2.00	1.51-2.65
Day-level NA	0.04	0.03-0.07	0.04	0.03-0.06
Day-level craving (lag-1)	0.21	0.12-0.35	0.20	0.12-0.34
Correlation, intercept and NA slope	0.11	-0.52-0.66	0.12	-0.39-0.58
Correlation, intercept and lag-1 craving slope	-0.73	-0.90- -0.34	-0.73	-0.91- -0.35
Residual	1.61	1.51-1.73	1.60	1.50-1.72
Fit Indices				
AIC	2482.11		2482.23	
BIC	2565.46		2584.13	

Note. $N=594$. * = $p \leq 0.05$. NA=Negative affect. PSE=Positive social experiences. NSE=Negative social experiences.

Research Question 2

The second research question was to explore whether daily social experiences (PSE and NSE) moderated negative-affect related changes in craving on the within-person level. Results from the model are shown in Table 2 and depicted in Figure 1. Findings revealed that within-person fluctuations in PSE moderated the association between NA and craving ($b = -0.005$; 95% CI = -0.009, -0.0003). The Johnson-Neyman technique was used to probe the interaction and identify the range of values of PSE at which the within-person association between NA and craving was significant (i.e., the region of significance). This analysis found that when number of PSE were outside the interval [5.07, 9.42] for the observed data, the NA-craving slope was significant. That is, on days when individuals had 5.07 more positive social experiences than usual or fewer, there was a significant positive within-day association between NA and craving. On days when individuals had 5.07 more positive experiences than usual, the within-day linkage between negative affect and craving was no longer significant. Results revealed that within-person fluctuations in number of NSE did not moderate the NA-Craving association ($b = 0.00$; *n.s.*).

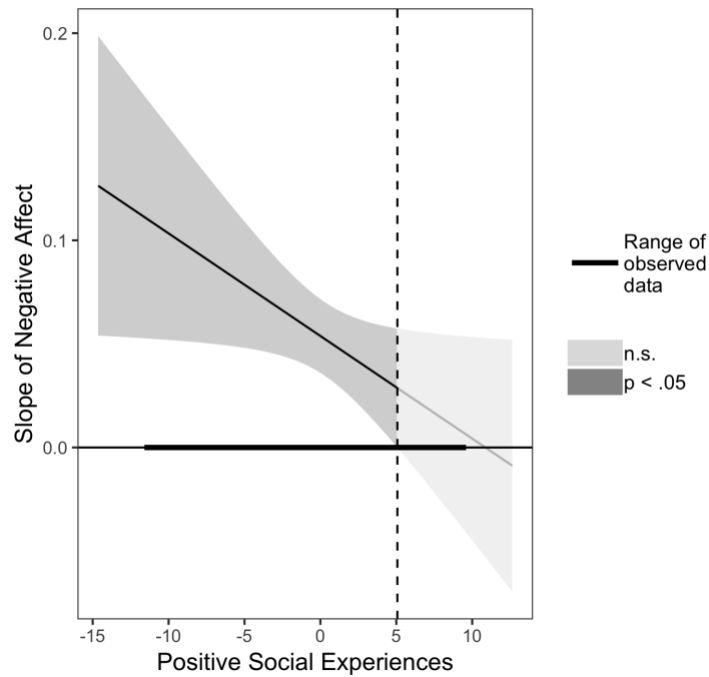


Figure 1. Effects of within-person negative affect \times positive social experiences on change in daily craving. This figure demonstrates how the intraindividual association between negative affect and craving is moderated by within-person fluctuation in the number of daily positive social experiences.

Research Question 3

The third research question was to explore whether within-person fluctuation in number of NSE interacted with within-person fluctuation in number of PSE to predict same-day craving. Results are shown in Table 2 and indicated that the interaction was non-significant ($b = -0.01$; *n.s.*). The three-way interaction between NA, PSE, and NSE predicting craving was also tested, and results revealed that this interaction was non-significant ($b = 0.00$; *n.s.*).

Supplemental Analyses

The premise of applying an EMA approach to craving is that it is important to investigate within-person processes that may potentiate or reduce craving (and thus potentially relapse risk), and that considering within-person associations among these constructs would reveal processes that between-person analyses would not. To examine this assumption, we reran the analyses presented above at the person level ($N = 73$). Results from a model examining the between-person effects of NA, PSE, and NSE on craving revealed that the association between NA and craving was significant ($b = 0.10$; 95% CI = 0.06, 0.13; $p < .001$). That is, experiencing higher levels of NA overall was associated with also experiencing higher overall levels of craving. Similarly, the association between NSE and craving was also significant at the between-person level ($b = 0.57$; 95% CI = 0.01, 1.13; $p < .05$). That is, experiencing more NSE overall was associated with also experiencing higher overall levels of craving. The association between PSE and craving was non-significant at the between-person level ($b = -0.16$; *n.s.*). These results are consistent with the within-person models. However, the interaction between NA and PSE was non-significant at the between-person level ($b = 0.01$; *n.s.*). These findings indicate that it is the within-person fluctuation in PSE driving this effect, illustrating the importance of parsing between-person and within-person variance.

Chapter 6

Discussion

The current study is one of the first to employ EMA methodology to explore the interactions between negative affect, positive and negative social experiences, and craving among individuals in residential treatment for opioid dependence. Data were drawn from the first EMA assessment of opioid patients in residential treatment. Most prior research in this area has examined between-person differences, despite the fact that treatment and recovery are dynamic daily processes that calls for investigation of within-person associations (Zheng et al., 2015). Although the relationship between negative affect and craving has received significant attention in the literature, including the EMA literature (Serre et al., 2015), this study is also one of the first to consider the potential role of daily social experiences in either enhancing or reducing relapse risk via direct impacts on craving or moderation of the negative affect-craving link. Research and theory (e.g., Relapse Prevention (RP) model; Witkiewitz & Marlatt, 2004) have tended to emphasize internal processes or contexts that confer risk for relapse, and less attention has been given to the role of social factors such as interpersonal conflicts and/or positive social support during treatment, and how they may interact with these intraindividual processes.

Overall, the present study found that craving increased on days when negative affect was higher than usual (after controlling for previous day's craving and usual negative affect), but there were significant interindividual differences in this intraindividual association. Craving also increased on days when individuals had more negative social experiences than usual (after controlling for previous day's craving and usual number of negative experiences). When testing interactions between affect and social experiences, results revealed that within-person variation in the number of daily positive social experiences moderated the within-person association between negative affect and change in daily craving. Findings are discussed below with implications for

future research.

Research Question 1

The study's first research question was to explore whether the within-person effects of negative affect, positive social experiences, and negative social experiences predicted changes in daily craving, after controlling for previous day's craving. Results showed a positive, within-person association between negative affect and craving, indicating that on days when negative affect was higher than usual, craving increased that same day relative to previous day's craving. This result is in line with prior research that has found that on days when negative affect is higher, craving also increases (e.g., Cleveland & Harris, 2010). It is also consistent with the Relapse Prevention (RP) model (Witkiewitz & Marlatt, 2004) and its extensions (Hunter-Reel et al., 2009; Roos & Witkiewitz, 2017), which all agree that negative affect is a dynamic internal state that can confer vulnerability to craving or relapse.

One potential explanation for this finding is that changes to the brain that occur during addiction, such as changes in reward and regulatory control mechanisms, alter emotional processing and increase sensitivity to negative mood, which extend into treatment and recovery (Heilig, Egli, Crabbe, & Becker, 2010; Koob & Le Moal, 2001). An acute increase in negative affect could trigger memories of the rewarding effects of the drug and overcome already comprised executive function circuits to produce an awareness of craving (Goldstein & Volkow, 2002; Volkow & Baler, 2014). Overall, an increase in negative affect that represents a significant fluctuation from one's normal daily affect state appears to be an intraindividual context that signals risk for elevated craving, and thus heightened vulnerability to relapse.

We also found evidence of interindividual differences in the intraindividual association between negative affect and craving. This result indicates that the strength of the negative affect-

craving relationship varies significantly across individuals. One potential explanation is that individuals differ in their reactivity to negative affect during withdrawal from opiates (Koob & Le Moal, 2001). Those with high negative affect reactivity may be especially vulnerable to craving on days when their negative affect is higher than normal, although others with lower negative affect reactivity may not experience the same level of risk. This information may provide an important step toward identifying *when* (e.g., on days of higher-than-normal negative affect) craving can increase, and potentially increase relapse risk. Future research should continue to explore the extent to which days of elevated negative affect lead to increases in same-day craving, and for which individuals this trigger is strongest.

In addition to the positive association between negative affect and craving, results also demonstrated a positive, within-person association between negative social experiences and craving. On days when individuals had more negative social experiences than usual, craving increased that same day relative to previous day's craving (and controlling for usual number of negative experiences). This finding is consistent with prior research indicating that negative social experiences significantly predict same-day levels of craving among college students in Twelve-Step substance abuse recovery (Cleveland & Harris, 2010) and extends it to a sample of opioid-dependent patients in residential treatment. One possible interpretation for the role of negative social experiences is that it depletes social recovery capital on a given day, limiting an individual's ability to cope with healthy strategies and eliciting an increase in craving.

Research Question 2

The second research question was to examine whether within-person associations between negative affect and craving were moderated by daily fluctuations in number of positive social experiences or negative social experiences (after controlling for previous day's craving).

Results revealed that daily positive social experiences moderated the within-person association between negative affect and craving, while daily negative social experiences did not. On days with fewer positive social experiences than usual, there was a significant positive within-day association between negative affect and craving. That is, individuals reported attenuated craving in response to higher-than-average negative affect days on days when they also reported more positive social experiences than usual, compared to days when they reported fewer positive social experiences than usual.

This finding suggests that the benefits of daily positive social experiences appear to be understood with respect to how they shape the ability to cope with negative affect. For instance, it may be that greater social support on a given day serves to boost recovery capital by providing a source of reward that is more desirable than the substance of abuse on days when negative affect is higher than usual, thus disrupting individuals' reactivity to negative affect as a cue that elicits craving. Avoiding overreaction in the face of negative affect may be a central component of avoiding craving. The current findings suggest that even if negative affect is greater than normal on a given day, those perceptions may not elicit an increase in craving on days when individuals also report more supportive interactions. Of note, the typical individual needed roughly five more positive social interactions than their usual number on a given day in order to buffer the link between negative affect and craving, suggesting that opioid-dependent individuals who have recently detoxed and are in the early stages of treatment need substantial amounts of social support in order to minimize increases in craving induced by negative affect.

These results support and extend both the Relapse Prevention model and previous research. The Relapse Prevention model emphasizes the interactions between internal processes and social environments, yet has historically been focused more on environments that confer risk. This study considers the dynamic nature of both negative and positive social environments, as well as their interactions with internal processes at the within-person level. Taken together with

the main effect associations, findings are consistent with prior research indicating that negative social experiences significantly predict same-day levels of craving (Cleveland & Harris, 2010), and that social support can lead to a reduced likelihood of relapse in the face of negative affect (e.g., Chassin, Sher, Hussong, & Curran, 2013). However, findings also extend existing literature to suggest that it is not the average number of positive and negative social experiences relative to others, but the number of social experiences relative to one's own usual amount and the timing with which they occur (i.e., having more positive social experiences than usual on days when negative affect is higher than normal) that matters when predicting craving. We ran all of these analyses on the between-person level and did not find the significant interaction effect presented here. By parsing out the within-person from the between-person variance, we found it was the within-person fluctuation in number of daily positive social experiences and their dynamic interactions with negative affect that determine when an individual is at risk for experiencing increases in craving from one day to the next.

These findings have important implications for intervention. In particular, just-in-time adaptive interventions (JITAI) are being employed that link real time data on behaviors or moods (collected via wearable devices and other sensors) to the type and timing of intervention that is delivered via smartphone, and can be tailored to individual needs (Vinci, Haslam, Lam, Kumar, & Wetter, 2018). JITAI have started to be implemented for alcohol use disorder (Gustafson et al., 2014) and smoking cessation (Naughton et al., 2016). The results from the current study suggest that these interventions have potential to intervene at crucial times (e.g., higher-than-usual negative affect and negative social experience days, and fewer-than-usual positive social experience days) and may mitigate the risk for craving by either targeting the negative mood and negative social interaction directly, or facilitating some form of in-person or remote social support.

Research Question 3

The third research question was to investigate whether positive and negative social experiences interacted to predict change in daily craving. Results showed that the interaction was not significant, indicating that negative social experiences had a direct association with increases in daily craving that was not buffered by positive experiences. Collectively, these findings demonstrate the dynamic nature of social variables and their importance during addiction treatment. Negative social experiences may be particularly detrimental to individuals in a treatment context who are in the early stages of recovery from opioid dependence, thus treatment providers should strive to create an environment that both limits negative interactions and provides positive social support within their residential facilities in order to prevent increases in daily craving.

Chapter 7

Limitations and Future Directions

Despite the contributions of this study to the literature, it is important to note a few limitations. First, because the data were collected from patients in a single residential treatment facility, the results may not generalize to other contexts. Second, the current study explored the relationships of affect and social experiences with craving, and not treatment outcome directly. Although craving has been found to have a strong association with relapse risk, the two are not the same. Third, asking participants to complete assessments four times per day could potentially influence their perceptions and reporting. For instance, multiple assessments per day could cause participants to become more aware of their affect, social experiences, and/or craving. Becoming more aware of positive social experiences could be beneficial, although the opposite might be true for negative affect/social experiences and craving. Future research is needed in order to determine whether reactivity bias of this type is present in individuals receiving treatment for addiction. Fourth, the timescales of the different measures might not all be the same and we do not know what the real timescales are. For example, we cannot tell with these data how long it takes before negative affect starts to effect craving (e.g., minutes, hours, days, etc.). Finally, focusing on a composite measure of negative affect is in line with prior research examining associations between affect and craving (e.g., Huhn et al., 2016), but future research might consider focusing on more specific affective states.

In addition, future research could do more to advance the understanding of the role of social experiences in mood, craving, and relapse in individuals in treatment. For example, although this study provides evidence that daily within-person fluctuations in number of positive social experiences can impact the link between negative affect and craving, it could also be the case that positive social experiences moderate the link between craving and relapse. Therefore,

more studies are needed that examine the protective role that social experiences could play at the daily, within-person level.

Chapter 8

Conclusion

Treatment and recovery from opioid addiction is a dynamic and lifelong process experienced by many individuals in the U.S. To our knowledge, this study is among the first to use an EMA design to examine how craving is predicted by the dynamic interplay between social experiences and negative affect at the within-person level among individuals in residential opioid treatment. This study demonstrated that both negative affect and negative social experiences were associated with increases in daily craving at the within-person level (after controlling for previous day's craving, usual negative affect, and usual social experiences). Days with more positive social experiences than usual protected against the effects of higher-than-usual negative affect days on increases in craving. These analyses provide insight into how internal and external factors interact at the daily level to predict craving, and thus increase relapse risk. Results from this study contribute to the field by taking a within-person approach to understanding socioemotional experiences within a treatment environment.

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