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An ecological momentary assessment analysis of pre-quit markers for smoking cessation failure

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Abstract

This study aimed to identify correlates of smoking cessation failure, a failure to establish abstinence during a quit smoking attempt. Identifying risk factors for early failure could facilitate the development of tailored interventions to promote cessation. The current study used existing ecological momentary assessment (EMA) data to investigate the extent to which pre-quit craving, negative affect, and recent smoking were associated with cessation failure in 374 smokers (189, 50.5% female). Subjects were prompted to complete 4–7 real-time reports of craving, negative affect, and recent smoking daily in the four days prior to quitting. Multilevel models of craving and negative affect (mean level, growth, volatility, and association with smoking) were estimated. Results indicated that recent smoking was associated with significantly lower craving among smokers who failed to quit than those who achieved a full day of cessation, but this held only among smokers who reduced smoking by at least 10% in the days preceding the quit attempt. Smokers who failed to quit on the quit day also experienced slower increases in negative affect in the days preceding the quit attempt than did initial abstainers, but delayed quitters and delayed cessation failures did not differ in negative affect trajectories. These results suggest that successful abstainers and cessation failures can be differentiated by specific dimensions of pre-quit craving and negative affect experiences, but the effects hold only in certain circumstances.

Keywords

Craving; Ecological Momentary Assessment; Smoking Cessation

Quitting smoking is notoriously difficult and the process of relapse can begin early during a quit attempt (Brandon, Vidrine, & Litvin, 2007; Fiore et al. 2008; Garvey, Bliss, Hitchcock, Heingold, & Rosner, 1993). Smoking cessation is a process marked by important phases, such as avoiding cessation failure (achieving a 24-hour abstinence period within the first few

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Disclosures

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weeks of a quit attempt; Shiffman et al., 2006). Cessation failure may derail abstinence goals. Smoking during a quit attempt may reflect the influence of risk factors for later smoking (such as nicotine dependence), but may also increase the risk of further smoking through various mechanisms. For example, low levels of smoking may potentiate withdrawal (Piasecki, Jorenby, Smith, Fiore & Baker, 2003a) and therefore increase the risk of later smoking. In addition, early smoking post-quit could yield subjective satisfaction that increases the odds of additional smoking (Shiffman, Ferguson, & Gwaltney, 2006). Once these processes start, returning to abstinence can be difficult. Indeed, early smoking is a robust, but not perfect (Marlatt & Gordon, 1990), predictor of later smoking (Kenford et al., 1994; Westman, Behm, Simel, & Rose, 1997). Developing interventions to prevent cessation failure may therefore set the stage for improved long-term abstinence rates, as sustained abstinence must begin with a first day (whether this occurs on a planned quit date or at another time).

Knowledge of the processes that precipitate early smoking may help direct cessation preparation efforts by suggesting risk factors to target in interventions to increase the likelihood that cessation attempts will get off to a good start. This paper will focus on identifying pre-quit risk factors for initial cessation failure, or smoking on the first day of a quit attempt, both to identify the dimensions of pre-cessation smoking experiences that may predict success in establishing abstinence and in an effort to identify useful targets for pre-quit interventions.

Negative reinforcement learning is one process that maintains smoking and prompts smoking lapses and relapses (Eissenberg, 2004). A contemporary negative reinforcement model of drug motivation (Baker, Piper, McCarthy, Majeskie & Fiore, 2004) asserts that avoidance of and escape from negative affect is the dominant motive for drug use and characterizes craving as an important state of awareness of drug motivation (Curtin, McCarthy, Piper, & Baker, 2006). This model asserts that a key dimension of negative affect and craving relevant to smoking is how well smoking alleviates negative affect and aversive cravings (Baker et al., 2004). According to this model, it is the degree to which smoking is negatively reinforcing, by alleviating affective distress or aversive craving, that is critical. What is central to smoking motivation is not how distressed an individual is in general or at a particular moment, but rather the degree to which changes in affect and craving are entrained to smoking in the individual. The model asserts that smokers who are chronically distressed are not necessarily those most likely to lapse or relapse. Instead, the smokers who find smoking the most helpful when distressed should be the most likely to lapse or relapse, given that quitting smoking reliably induces distress (Welsch et al., 1999). Smokers may vary in the degree of this kind of entrainment they experience, which may help explain why the literature on the affective consequences of smoking (i.e., the extent to which smoking relieves affective distress) has been mixed (Kassel, Stroud & Paronis, 2003) and why smokers on average do not frequently cite negative affect as a motive for smoking (Piasecki, Richardson, & Smith, 2007).

Much research supports the importance of negative affect and craving as predictors of lapse and relapse (Brandon, Vidrine, & Litvin, 2007; Shiffman, Paty, Gnys, Kassel, & Hickcox, 1996; Shiffman et al., 1997), but affect and craving are typically assessed in the post-quit period, when some smokers have already returned to smoking. Examining the negative affect and craving profiles of individuals prior to quitting may help identify smokers at risk before they have started down the road to relapse. Indeed, recent research supports the value of examining pre-quit and very early changes in negative affect and craving in the prediction of later smoking cessation outcomes (Cofta-Woerpel, McClure, Urbauer, Cinciripini, & Wetter, 2011; McCarthy, Piasecki, Fiore, & Baker, 2006). These data suggest that negative

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affect and craving profiles pre-quit or on the quit day may identify smokers who are likely to have early returns to smoking and a reduced likelihood of later abstinence.

Modeling pre-quit changes in craving and negative affect after recent smoking may help link pre-quit learning experiences to initial cessation failure. Studies of *ad lib* smoking have found that smokers report the highest levels of craving and negative affect right before smoking occurs, and the lowest levels immediately after smoking (Carter et al., 2008). In addition, smokers who expect smoking will alleviate negative affect also tend to relapse at higher rates (Wetter et al., 1994). Self-reported tendency to experience strong cravings when deprived of nicotine is also predictive of relapse (Piper et al., 2008). This evidence is based on trait-like measures of negative affect and craving. Recent research, however, has shown negative affect and craving to be highly dynamic, and suggest that fluctuations in these constructs have important implications for later smoking (McCarthy, Piasecki, Fiore, & Baker, 2006; Piasecki et al., 2003a; Piasecki, Jorenby, Smith, Fiore & Baker, 2003b; Shiffman et al., 1997). In light of this evidence, it is important to treat negative affect and craving as dynamic rather than static in models of cessation failure or early lapse or relapse risk.

Modeling multiple dimensions of pre-quit craving and negative affect may also help uncover their relations with cessation failure. Research has found that multiple dimensions (mean levels, linear and quadratic growth, and volatility) of withdrawal can improve relapse predictions, with each dimension making a significant independent contribution to model fit (Piasecki et al., 2003a; Piasecki et al., 2003b). Relations between craving or negative affect and cessation failure may vary as a function of the specific dimension assessed. For example, volatility in craving levels may predict cessation failure, while mean craving level does not. This variability may limit the apparent extent of craving and negative affect relations with cessation failure unless multiple dimensions are modeled.

Lastly, it is also important to identify the appropriate timescale to examine relations between negative affect and craving and later smoking, as past research suggests that there are optimal timeframes for detecting such effects. For example, a study by Shiffman and Waters (2004) found that smoking lapse was predicted by negative affect dynamics in the four hours prior to lapse, but not over a longer period of days. Similarly, we anticipate our potential pre-quit risk factors would be more strongly related to smoking episodes that occur sooner rather than later during a quit attempt.

The current study assessed pre-quit negative affect and craving as potential markers of smoking on the first day of a quit attempt in the hope that identifying risk factors may facilitate the future development of interventions that promote early abstinence in at-risk smokers. The primary markers of interest were the degree to which recent smoking was associated with lower negative affect and craving within subjects in the days preceding a quit attempt. We also examined whether or not craving, negative affect, and smoking relations were influenced by pre-quit reductions in cigarette consumption since many smokers reduce cigarette consumption prior to quitting (Hughes, Callas, & Peters, 2007) and this may alter relations between cigarettes smoked and affect or craving. In addition, the study tested the extent to which pre-quit negative affect and craving dimensions (mean level, linear and quadratic growth, and volatility) that have been found to predict later abstinence outcomes (McCarthy, Piasecki, Fiore, & Baker, 2006; Piasecki et al., 2003a; Piasecki et al., 2004b) would predict initial cessation status. The study also examined whether pre-quit craving and negative affect dimensions were related to later cessation failure over the first two weeks of a quit attempt (i.e., failing to achieve a full day of abstinence in that two week period). To achieve these aims, this study used ecological momentary assessment (EMA; Stone & Shiffman, 1994) to investigate real-time craving, negative affect, and recent

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smoking during a four-day time period prior to a target-quit day. A four-day interval was selected because previous work by Piasecki and colleagues (2003b) found that a composite of withdrawal symptoms increased over four days prior to a first lapse.

Method

Participants

The current study used data collected during a double-blind, randomized, placebo-controlled clinical trial of bupriopion SR and individual counseling for smoking cessation (McCarthy et al., 2008a; McCarthy et al., 2008b). Participants were recruited in the Madison, Wisconsin area. Inclusion criteria included: being 18 years of age or older, smoking a minimum of 10 cigarettes per day, having an expired carbon monoxide (CO) level of 10 parts per million or greater, motivation to quit smoking of at least three on a four-point scale, being able to read and write English, and willingness to fulfill study requirements. Individuals were excluded on the basis of serious psychiatric conditions (i.e., bipolar disorder or psychosis), current depression, current heavy drinking or illegal drug use, use of other tobacco products in the last seven days, current use of stop-smoking treatments, participation in a stop smoking study within the last 30 days, living with someone enrolled in the study, and contraindications to bupropion SR use (e.g., uncontrolled hypertension, history of seizure disorder, past negative reactions to bupropion, risk of pregnancy, or current breast feeding).

Of the 463 enrollees in the study, 60 (13.0%) withdrew from the study prior to the target-quit date. As in previous cessation failure studies (Japuntich et al., 2011; Piper et al., 2009; Shiffman et al., 2006), these 60 subjects were excluded from analyses. An additional 29 (6.3%) subjects did not complete enough pre-quit reports to be included in multilevel models. Baseline characteristics of the 374 subjects (189 female) included in multilevel models are shown, by initial cessation failure status, in Tables 1 and 2. The same 374 subjects were used in analyses of initial (i.e., first day) and later (i.e., first two weeks) cessation failure status.

Measures

Baseline Assessment—All participants provided demographic information and baseline self-report measures of affect (the Positive and Negative Affect Schedule, or PANAS, Watson, Clark, & Carey, 1988), depressive symptoms (the Center for Epidemiologic Studies Depression Scale, or CES-D, Radloff, 1977), nicotine withdrawal (the Wisconsin Smoking Withdrawal Scale, or WSWS, Welsch et al., 1999), and nicotine dependence (the Fagerström Test of Nicotine Dependence, or FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991), and the Wisconsin Inventory of Smoking Dependence Motives, or WISDM-68, Piper et al., 2004). A full description of the study protocol is provided elsewhere (McCarthy et al., 2008a; McCarthy et al., 2008b).

Ecological Momentary Assessment—Participants' self-reported thoughts, emotions, withdrawal symptoms, and smoking behaviors were assessed via Electronic Diary (ED). The EDs (Palm Vx Palmtop Computer, Palm, Inc., Santa Clara, CA) were programmed by invivo data Inc. (Pittsburgh, PA, USA) to administer between four and seven reports daily for two weeks pre- and four weeks post-quit. Each report took approximately two minutes to complete. Reports occurred at pseudo-random time intervals separated by at least 30 minutes during each participant's waking hours.

Momentary reports assessed craving and affect just prior to the ED prompt, as well as the number of cigarettes smoked since the last report (0–20 cigarettes). Participants rated their agreement with craving and affect items on an 11-point scale ranging from 1 (No!!) to 11

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(Yes!!). Items assessing craving included questions about the "urge to smoke" and whether or not the individual was "bothered by desire to smoke" that were averaged to index craving. Results were the same when craving was assessed by the "urge to smoke" alone. Items assessing negative affect included questions about how "tense or anxious," "sad or depressed," or "restless" an individual was just before the prompt that were averaged to yield a summary score. Factor analyses of random report data conducted by McCarthy et al. (2008b) found that craving and negative affect loaded on separate factors. A confirmatory factor analysis taking into account the nesting of repeated observations within subjects confirmed the hypothesized mapping of urge and negative affect items on separate latent variables in an excellent fitting model (*Chi square*=5.22, *p*=.26, *CFI*=.99, *RMSEA*=.003) with the current data.

Procedures

All study procedures were approved by the Institutional Review Board at the University of Wisconsin School of Medicine and Public Health. Participants were recruited via mass media advertising. Individuals who passed an initial telephone screening for eligibility were invited to a group orientation session for additional screening (including CO testing) where written informed consent was obtained. Following a subsequent physical examination, participants were formally enrolled and randomized into one of four cells in a 2 (active bupropion SR v. placebo) × 2 (counseling v. no counseling) factorial design. All participants received either medication or placebo from one week prior to a target quit day through eight weeks post-quit. Participants were also assigned to either eight sessions of brief (10-minute) individual cessation counseling or a no counseling condition, that included only medication management and assessment. Participants attended a total of 13 study visits over 11 weeks. Maximum remuneration for participation was $200, with payment contingent upon ED return.

Cessation Failure

This study investigated affect and craving relations with two definitions of cessation failure. Initial cessation failure was defined as the failure to abstain for the first 24 hours of an attempt to quit smoking. Later cessation failure was defined as failure to establish a full calendar day of abstinence within the first two weeks of a smoking cessation attempt. Smoking was discerned from time-stamped participant ED self-reports and a retrospective timeline follow-back smoking calendar completed at each study visit. Participants were prompted several times per day by the investigators to complete reports. Additionally, participants were instructed to initiate reports detailing the first five instances of smoking post-quit. Smokers were coded as smoking on a given day if any of the smoking data collected that day, via investigator-initiated or subject-initiated ED report or smoking calendar, indicated that smoking occurred.

A total of 133 participants (35.6% of the sample included in analyses) reported smoking on the first day of the quit attempt and were considered initial cessation failures. Initial cessation failure was highly predictive of later CO-confirmed smoking status. Those who smoked on the target quit day were roughly a quarter as likely as those who quit on the target quit day to be abstinent for seven days at the end of treatment (eight weeks post-quit, *OR*=.278, *95% CI*=.158–.488, $p < .001$).

A total of 60 participants (16.0% of the sample) were considered later cessation failures because they did not establish a full calendar day of abstinence within the first two weeks of the quit attempt. This definition of later cessation failure is consistent with the conventional cessation failure definition (Shiffman et al, 2006) although the time period allowed for smokers to establish initial abstinence varies from study to study (e.g., one week in Piper et

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al., 2009; two weeks in Japuntich et al., 2011; three weeks in Shiffman et al., 2006). The rate of later cessation failure in our sample is similar to previous reports of cessation failure (11.9% failed to establish abstinence over 2 weeks; Japuntich et al., 2011; 16.5% failed to establish abstinence over 1 week; Piper et al., 2009). Failing to abstain for even a day in the first two weeks of a quit attempt was also highly determinant of later smoking status. None of the 60 participants who failed to quit in the first two weeks achieved CO-confirmed seven-day point-prevalence abstinence at the end of treatment.

Data Analysis

Multilevel models (Raudenbush & Bryk, 2002) were used to test relations between cessation failure and both craving and negative affect dynamics (mean severity, linear and quadratic growth, and associations with recent smoking). Momentary reports of negative affect, craving, and a time-varying smoking covariate indicating whether or not smoking occurred in the past two hours were nested within individuals in these multilevel models. A two-hour time frame was chosen based on previous research that found smoking influenced negative affect up to two hours later (Chandra, Scharf, & Shiffman, 2011). Analyses were conducted with Hierarchical Linear Modeling (HLM) Version 6.04 software (Raudenbush, Bryk, & Congdon, 2007).

Craving and negative affect were examined in two separate models. Each model predicted momentary negative affect or craving as a function of an intercept capturing mean symptom level, a time variable in day units capturing average linear growth, time squared capturing quadratic growth, and the time-varying smoking covariate. Time was centered at the midpoint of the assessment period. In equation format, the starting level-1 model fit to the data was $Y=\pi_0+ \pi_1(\text{Day})+ \pi_2(\text{Day}^2)+ \pi_3(\text{Recent Smoking})+e$, where Y equals craving or negative affect, π_0 is an intercept capturing the mean level of the dependent variable over the four-day pre-quit period, π_1 is the average linear slope across the four days, π_2 is the quadratic growth coefficient, and π_3 reflects the mean difference in craving or negative affect between reports in which no smoking occurred in the past two hours (the reference group) vs. those in which smoking occurred. Models were simplified when results indicated no average quadratic or linear growth occurred and there was either no significant variability in growth or individual quadratic and linear growth could not be estimated reliably (i.e., reliability was below .70).

Cessation failure (0=abstinent, 1=smoked) was entered as a level-two explanatory variable for intercept, growth (when retained in the model), and smoking coefficients. Although looking at cessation failure as a level-2 explanatory variable in models of pre-quit craving and affect reverses the temporal ordering of predictor and outcome, it also prevents power loss that occurs due to shrinkage of variance in HLM growth estimates when individual estimates are extracted from HLM models. Models included additional relevant covariates such as baseline craving (in craving models) or negative affect (in negative affect models) and control variables (sex, racial minority status, income, nicotine dependence level, medication condition [bupropion SR vs. placebo], and baseline depressive symptoms) linked with cessation outcomes in past research (Glassman et al., 1990; Kozlowski, 1994; Lawrence, 2003; McCarthy et al., 2008a; Wetter et al., 1999). We also included a binary control variable capturing whether or not a smoker reduced the number of cigarettes smoked per day by 10% or more during the four-day assessment window (1=cut back by 10% or more [reported by 42.8% of subjects], 0=did not reduce smoking) and an interaction term between this smoking reduction indicator and cessation failure status to determine whether or not any differences in craving or affect experiences across cessation failure groups were conditional on smoking level pre-quit. Non-significant individual-level covariates were trimmed from the final models.

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To assess relations between pre-quit craving and negative affect volatility and cessation failure, logistic regression analyses run with PASW software (Rel. 18.0.0. 2009. SPSS: An IBM Company) predicted cessation failure from the average squared deviation between observed and predicted craving or negative affect scores for each subject, following the steps outlined in Piasecki and colleagues (2003a). Separate volatility indices were calculated for negative affect and craving. Empirical Bayes estimates of individual subjects' intercepts and slopes in the final HLM models were included in logistic regressions to control for mean symptom levels and symptom growth pre-quit. Regression models also included the control variables used in HLM models (sex, minority status, income, nicotine dependence, medication status, depressive symptoms, and pre-quit smoking reduction).

Results

EMA Adherence

Participants completed 77.3% of the 20 reports prompted randomly over the four days before a quit attempt. This adherence rate is close to the 80% adherence rate recommended for EMA data (Stone & Shiffman, 2002).

Initial Cessation Failure

Craving—The final level-1 HLM model for momentary craving was: $Y=\pi_0 + \pi_1$(Recent smoking)+e (see Table 3). The linear and quadratic growth terms were dropped due to non-significance when fixed and unreliability when allowed to vary across subjects.

The final level-2 model was $\pi_0 = \beta_{00} + \beta_{01}$(Baseline WSWS Urge)+ β_{02}(Baseline WISDM Craving)+ β_{03}(Initial Cessation Failure)+r_0 for the intercept, which was significantly positively related to baseline WSWS urges and the WISDM dependence subscale capturing vulnerability to craving. Non-significant control variables (sex, minority status, income, nicotine dependence, medication status, depressive symptoms, and pre-quit smoking reduction) were trimmed from the model. The r_0 term indicates that the intercept was random (i.e., allowed to vary across subjects). Also at level-2, the model specified the following equation for the smoking coefficient: $\pi_1 = \beta_{10} + \beta_{11}$ (Initial cessation failure) + β_{12} (Smoking reduction) + β_{13} (Initial cessation failure X smoking reduction). All other covariates were non-significant and were trimmed from the final model. There were no significant main effects of pre-quit smoking reduction or cessation failure, but there was a significant interaction between them. The interaction coefficient in the equation for the smoking coefficient indicated that smokers who smoked on the quit day reported significantly lower craving after pre-quit smoking than did smokers who quit successfully, but only when the smoker had reduced smoking by 10% or more pre-quit. Among smokers who continued to smoke normally in the pre-quit period, recent smoking relations with craving did not differentiate quit day failures vs. abstainers. The interaction between initial cessation failure and pre-quit smoking reduction appears to be of small magnitude (a difference of 28% a standard deviation in craving). We were not able to estimate the magnitude of this effect by examining the odds ratio for individual smoking-craving coefficients as predictors of initial cessation failure in a logistic regression because we were not able to estimate these reliably (reliability for this coefficient when allowed to vary across subjects was only .574). Because of this, we treated this coefficient as fixed in the model.

Craving volatility in the four days before quitting (captured by the mean squared residuals for the model described above) was unrelated to initial cessation failure. A logistic regression model predicting initial cessation failure indicated that empirical Bayes estimates of neither mean pre-quit craving (*B*=0.003, *SE*=0.060, *Wald*=0.002, *OR*=1.003, *95% CI*=0.891–1.128) nor the mean squared residual in craving (*B*= −0.024, *SE*=0.043,

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Wald=0.305, *OR*=0.976, *95% CI*=0.897–1.063) was significantly predictive of initial cessation failure. Pre-quit smoking reduction also did not predict initial cessation failure (*B*= 0.015, *SE*=0.234, *Wald*=0.004, *OR*=1.016, *95% CI*=0.642–1.607). Cessation failure was also not predicted by sex, minority status, income, nicotine dependence, medication status, or depressive symptoms, and all control variables were trimmed from the model.

Negative affect—The final model (Table 4) of momentary negative affect was $Y=\pi_0 + \pi_1(\text{Day}) + \pi_2(\text{Recent smoking})+e$. The quadratic coefficient was dropped because it could not be estimated reliably when allowed to vary across subjects and was not significantly different from zero, on average.

The final level-2 model was: $\pi_0 =\beta_{00}+ \beta_{01}(\text{Baseline FTND})+\beta_{02}(\text{Baseline WSWS Anxiety}) +\beta_{03}(\text{Baseline WSWS Sadness})+\beta_{04}(\text{Baseline N-PANAS})+\beta_{05}(\text{Initial Cessation Failure})+r_0$ for the intercept; $\pi_1 =\beta_{10}+\beta_{11}(\text{Age}) +\beta_{12}(\text{Baseline WSWS Anxiety})+ \beta_{13}(\text{Baseline WSWS Sadness})+\beta_{14}(\text{Initial Cessation Failure})$ for the slope; and $\pi_2=\beta_{20}+\beta_{21}(\text{FTND})+\beta_{23}(\text{Initial Cessation Failure})$ for the smoking covariate. All other level-2 covariates, including sex, minority status, and smoking reduction, were dropped from the model due to non-significance.

Pre-quit mean negative affect reported via ED was positively significantly related to baseline measures of negative affect (N-PANAS) and affective withdrawal symptoms (WSWS Anxiety and Sadness subscales), and nicotine dependence (measured with the FTND). Change in negative affect over the four days leading up to the quit attempt was also related to baseline anxiety and sadness withdrawal subscale scores. Smokers higher in anxiety at baseline experienced faster growth in negative affect as the quit day approached compared to smokers with lower baseline anxiety, whereas those higher in baseline sadness experienced slower distress growth than smokers with lower baseline sadness. Older participants experienced steeper increases in negative affect pre-quit, on average. Initial cessation status was also related to pre-quit negative affect growth, such that successful quitters experienced steeper increases in negative affect pre-quit than did smokers who smoked on the target quit day, on average. This difference was small in magnitude (16% of a standard deviation in negative affect). Over the four day period, on average, those who abstained from smoking on the quit day experienced a one-half point increase in negative affect (rated on an 11-point scale). Smokers who failed to quit initially experienced an average increase of only a fifth of a point during this time frame.

Initial cessation failure was unrelated to the association between recent smoking and negative affect pre-quit. Although recent smoking was only marginally related to lower negative affect overall, smokers with higher FTND scores reported significantly lower negative affect after recent smoking (compared to reports completed more than two hours after smoking) than did less dependent smokers.

Volatility of pre-quit negative affect was also not associated with initial cessation failure. A logistic regression model predicting initial cessation failure indicated that the empirical Bayes estimates of the intercept (*B*= −0.016, *SE*=0.082, *Wald*=0.038, *OR*=0.984, *95% CI*=0.838–1.156) and volatility (mean squared deviation) in negative affect (*B*=0.010, *SE*=0.101 *Wald*=0.010, *OR*=1.010, *95% CI*=0.829–1.231) were both unrelated to initial cessation failure. No control variables predicted cessation failure and all control variables were subsequently trimmed from the model.

Later Cessation Failure

Later cessation failure (failing to achieve a full day of abstinence in the first two weeks of the quit attempt) was examined in separate models. The modeling strategy described above

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was used; the only difference was that the initial cessation failure variable was replaced with this more conventional definition of cessation failure. Results in these models were similar to those reported above, except that the relation between later cessation failure and the slope in momentary negative affect pre-quit was no longer significant (*Est* = −0.038, *SE* = 0.367, *t* = −1.026, *p* = .305).

Discussion

Results suggested that people who fail to quit smoking during a quit attempt may differ from those who quit successfully in subtle and complex ways. The degree to which craving was lower following recent smoking than other occasions was associated with initial and later cessation status, but only among smokers who reduced the number of cigarettes smoked per day over the four days preceding a quit attempt. Those who failed to quit on the quit day also showed less negative affect growth pre-quit than smokers who achieved total abstinence on the quit day. The rate of growth in negative affect was small and not significantly related to delayed smoking cessation status (i.e., achieving a full day of abstinence up to two weeks post-quit), however. Mean negative affect levels and smoking-affect relations pre-quit did not differ as a function of cessation status. Craving and negative affect volatility indices over the four-day pre-cessation period were also unrelated to cessation status. These results suggest that markers for cessation failure may be subtle and conditional.

Initial cessation (quitting on a target quit day) is an important intermediate outcome in the smoking cessation process. In order for lasting change to occur, initial change must occur first. The current study demonstrated that smokers who failed to quit on a target quit day were very likely to still be smoking at more distal time points, such as eight weeks post-quit. Indeed, only 16 (12%) of people who smoked on the quit day established seven-day point-prevalence abstinence at the end of treatment in the current study. Thus, full, lasting recovery from smoking during the early post-quit period was rare, as in past research (Kenford et al., 1994; Westman, Behm, Simel & Rose, 1997). Initial success or failure in quitting is therefore an important intermediate outcome, and being able to predict this outcome may facilitate the prevention of cessation failure through intervention.

In this study, pre-quit average levels of craving did not differentiate those who quit smoking from those who failed to quit. Results supported the validity of the craving measure, as mean craving levels rated on the electronic diary were significantly and positively related to nicotine dependence and other indices of craving collected at baseline. Experiencing greater craving did not, however, signal increased risk of initial or delayed cessation failure in this sample. Instead, the dimension of craving that was related to cessation status was the degree to which craving was lower following smoking in the past two hours than at other times. This relation only emerged, however, in the context of smoking reduction pre-quit. That is, smoking-craving relations only differed among successful vs. failed quitters when smokers had reduced their smoking by 10% or more during the assessment period. This suggests that reducing smoking prior to quitting may create an opportunity to strengthen negative reinforcement learning (i.e., learning that smoking alleviates craving) that places vulnerable smokers at risk of failure.

This relation may not be evident in smokers who continue to smoke heavily prior to quitting. Reducing smoking may not affect every smoker in this way. In this sample, there was no main effect of smoking reduction on the magnitude of the coefficient linking smoking to craving. Other research has found that pre-quit reductions in smoking may increase smoking cessation success in smokers engaging in nicotine pre-loading (i.e., wearing the patch for two weeks prior to a target quit day) (Rose, Herskovic, Behm, & Westman 2006) and in smokers cutting down in a highly structured program (Cinciripini, Lapitsky, Seay, et al.,

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1995). Decreased reinforcement from smoking during reduction in these contexts may be contributing to cessation success (Rose, 2011). Reducing smoking in the absence of nicotine pre-loading or a highly structured reduction schedule, however, may create an opportunity for reinforcement of smoking via craving relief that some smokers experience and places them at risk of cessation failure. Although this effect was small, it was also robust and persisted across many different permutations of the model, including models that examined delayed rather than initial cessation failure. Further research is necessary to clarify under what circumstances pre-quit smoking reduction affects smoking cessation.

The momentary craving models run in this study indicated that there was no significant growth in craving in the four days pre-quit, on average, and we were unable to estimate individual growth reliably during this brief assessment period. As such, we did not test the relation between cessation failure and pre-quit craving trajectories in the current sample. It may be that our brief assessment window reduced our ability to estimate growth reliably or that there was little growth or variability in growth pre-quit, as people were still smoking regularly (even if at reduced levels).

The final dimension of craving experience that we examined in this study was volatility, or the mean squared deviation between observed and predicted scores for each individual in our random intercept model. This index of volatility was not significantly related to initial or delayed cessation failure. Previous work documenting relations between withdrawal symptom volatility and relapse examined volatility in daily symptom ratings collected over weeks in the post-cessation period. There may be insufficient volatility in craving in the brief pre-quit period we examined to detect relations with cessation failure. It is also possible that post-cessation withdrawal processes give rise to meaningful, predictive volatility and that these relations are not observed when smokers are not nicotine-deprived.

Results from the negative affect models also suggested that some dimensions of affective experience pre-quit are more closely related to cessation failure than others. Although average levels of negative affect during the four-day pre-quit period were significantly related to baseline measures of negative affect as anticipated, average negative affect level was unrelated to cessation failure in any model. In contrast, the trajectory in negative affect pre-quit was related to cessation status. Specifically, smokers who failed to quit on the first day of the quit attempt had significantly shallower slopes (i.e., weaker growth) in negative affect in the four days leading to the quit attempt than did smokers who abstained on the quit day. The magnitude of this effect was small and the direction of this effect was unexpected, as negative reinforcement theories (Baker et al., 2004; Eissenberg, 2004) and research on mood and smoking outcomes (Glassman et al., 1990) would predict that increasing negative affect pre-quit would stoke motivation to smoke on the quit day and therefore increase cessation failure risk. We note, too, that this small effect did not persist when the definition of cessation was modified and anyone who quit for a full day within the first two weeks was considered a successful quitter. This lack of consistency in not surprising, given that expanding the cessation failure assessment window likely dilutes relations between pre-quit variables and more distal abstinence. It is important to note, however, that we did not include negative affect on the quit day in our pre-quit period, and past research has documented discontinuity (i.e., jumps) in negative affect on the quit day (McCarthy et al., 2006; 2008b). As such, people who failed to quit may have experienced shallower increases in negative affect over the days leading up to a quit attempt, but still experienced a jump in negative affect on the quit day that set them up for failure.

Additionally, modest increases in negative affect before quitting could be a normative and adaptive anticipatory reaction to the upcoming challenge of quitting, and not necessarily an impediment to cessation. The ratings of negative affect in our sample were low (an average

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of 3.093 on an 11-point scale), as was the average increase of pre-quit negative affect (.126 points per day among successful quitters and .048 per day among those who failed to quit). The absence of a modest anticipatory increase in negative affect before quit day may be an indicator that one is not fully committed to quitting or preparing oneself for the work of quitting. Alternatively, smokers who experienced mild negative affect increases before quitting may be demonstrating an ability to tolerate distress, which is predictive of success in quitting (Brandon, Herzog, Juliano, et al., 2003; Brown, Lejuez, Kahler, Strong, & Zvolensky, 2005) Further research is necessary to determine what drives these differences in pre-quit negative affective growth between initial cessation failures and abstainers and how pre-quit growth impacts smoking on the first day of a quit attempt.

Growth in negative affect pre-quit was related to other smoker characteristics as well. Older smokers and smokers with higher nicotine dependence levels (as measured by the FTND) and baseline anxiety experienced greater negative affect growth pre-quit, but smokers with higher baseline sadness experienced less negative affect growth pre-quit. Older smokers may have more experience quitting or more urgent motivation to quit that might prompt them to experience more negative arousal as the quit day approaches, and more dependent or anxious individuals may expect more difficulty quitting and may, therefore, experience more anticipatory anxiety. Individuals with elevated sadness, however, may be more prone to withdraw from the pending quit attempt in some ways, which may attenuate affect. Additional research is needed to determine what processes drive pre-quit negative affective growth, why it varies between smokers, and its possible impact on initial cessation failure.

The other dimensions of negative affect examined (association with smoking and volatility) were not significantly related to cessation failure in any model. As such, our hypothesis that the degree to which smoking reduces affective distress would be a marker for difficulty quitting was not supported. It is important to note that affect ratings were low, overall, and this lack of variability may have reduced our ability to detect a relation with cessation failure. The apparent floor effect with negative affect ratings is consistent with the idea that most smoking occurs in response to preconscious affective distress (i.e., very low levels of distress that are sufficient to prime smoking behavior but insufficient to capture awareness; Baker et al., 2004), but our data to not speak to this possibility directly, as we relied on self-report measures of affect.

Another possible explanation for the lack of association between negative affect and recent smoking may be that smoking only consistently relieves negative affect arising from withdrawal (Baker et al., 2004), and this relation is not readily observed during *ad lib* smoking (Kassel, Stroud, & Paronis, 2003). The lack of detectable relations between smoking and affect may also reflect the frequent and regular smoking exhibited by our highly dependent sample regardless of emotional state or other contexts. That is, smokers who are highly dependent on tobacco may smoke as often in the context of low negative affect as in the context of distress. Highly dependent smokers may not wait for a precipitant to smoke, and may smoke automatically without affective provocation. We cannot tease apart these possibilities in the current study. Research in less dependent smokers (i.e., adolescents and intermittent smokers) may yield additional insight into smoking and affect relations during *ad lib* smoking.

Limitations

First, the correlational nature of our analyses precludes any causal inferences regarding smoking effects on craving, the impact of smoking relief of craving on cessation failure, or the predictors or consequences of pre-quit changes in negative affect. Although our results are consistent with causal hypotheses (e.g., that reducing smoking prior to quitting creates an opportunity to strengthen learning that smoking is negatively reinforced by craving relief

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that, in turn, increases risk of cessation failure), the observed relations could also simply reflect the influence of unknown nuisance or substantive influences. Low reliability in model estimates of linear and quadratic growth hampered our ability to estimate individual slopes and link variability in growth to cessation status, even when we extended the pre-quit assessment period to two weeks (results not shown). Inadequate adherence to electronic diary alarm schedules may also have contributed to the lack of reliability in growth estimates, although the response rate in this sample (77.3%) was acceptable. It remains possible, however, that heightened negative affect or craving may make participants less disposed to complete random prompts and that missing data are therefore not missing at random. In addition, we did not account for complex, non-linear trends in craving and affect. For example, we did not estimate circadian effects within days or look at day of the week effects. There may be complex patterns in craving or affect within or across days that we did not model. The generalizability of these findings may also be limited. Study requirements demanded participants commit to an intensive assessment and treatment program, whereas most smokers in the population choose to quit without any treatment (Hughes & Burns, 2001).

Conclusions

The current study identified two candidate markers for cessation failure during attempts to quit smoking. The first candidate marker, negative associations between recent smoking and craving ratings, held for smokers who reduced their smoking by 10% or more over the four days leading to the quit day, but not for smokers who continued to smoke at a stable level during this period. Thus, a candidate marker for cessation failure worthy of additional study is the degree to which smoking relieves craving during a period of reduced smoking. The second candidate marker was attenuated growth in negative affect in the immediate pre-quit period. This marker was associated with immediate, but not delayed, cessation failure. These patterns of results were complex, unexpected and should be interpreted as preliminary pending replication. Future research could attempt to replicate these results and explore the extent to which there are optimal levels of anticipatory negative affect that facilitate the cessation process and then explore ways to promote these optimal levels of negative affect in prospective quitters. Taken together, the results of this study suggest that smokers who achieve brief cessation differ from those who fail to quit for a full day in identifiable ways that may reflect important aspects of drug motivation (i.e., negative reinforcement learning that smoking alleviates craving) and the change process (i.e., optimal levels of negative arousal facilitate change). Future research is needed to more fully explore these possibilities.

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Table 1

Sample characteristics as a function of initial cessation status.

Variable	Value	Initial Abstainers (n=241) n (%)	Initial Cessation Failures (n=133) n (%)	χ^2
Sex	Female	115 (47.7%)	74 (55.6%)	2.151
Ethnicity	Hispanic	3 (1.2%)	1 (1.0%)	0.197
Race	White	221 (91.7%)	113 (85.0%)	6.040
	African-American	13 (5.4%)	10 (7.5%)	
	Other	7 (2.9%)	10 (7.5%)	
Marital Status	Married	115 (47.7%)	50 (37.6%)	5.657
	Separated or Divorced	43 (17.8%)	34 (25.6%)	
	Never Married	58 (24.1%)	30 (22.6%)	
	Cohabitating	20 (8.3%)	15 (11.3%)	
	Widowed	5 (2.1%)	2 (1.5%)	
Education	Less than high school degree	6 (2.5%)	5 (3.8%)	3.249
	High school	47 (2.0%)	33 (24.8%)	
	Some college	122 (50.6%)	64 (4.8%)	
	College degree or greater	66 (27.4%)	31 (23.3%)	
Employment Status	Employed	204 (84.6%)	105 (79.0%)	12.279
	Unemployed	11 (4.6%)	7 (5.3%)	
	Homemaker	9 (3.7%)	6 (4.5%)	
	Student	8 (3.3%)	2 (1.5%)	
	Retired	5 (2.1%)	6 (4.5%)	
	Disabled	1 (0.4%)	4 (3.0%)	
Household Income	< $25,000	59 (24.5%)	45 (33.8%)	12.570*
	$25,00–$34,999	35 (14.5%)	19 (14.3%)	
	$35,000–$49,999	49 (20.3%)	27 (20.3%)	
	>$50,000	90 (37.3%)	40 (16.6%)	

* $p \leq .05$

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Table 2

Age and smoking characteristics as a function of initial cessation status.

Variable	*Initial Abstainers (n=241) M (SD)*	*Initial Cessation Failures (n=133) M (SD)*	*t*
Age	38.17 (11.55)	41.12 (12.41)	−2.306*
Cigarettes per day	20.81 (9.69)	23.14 (10.39)	−2.170*
CO level	23.97 (11.58)	25.47 (11.82)	−1.190
FTND	4.82 (2.40)	5.44 (2.18)	−2.510*
N-PANAS	16.85 (5.90)	17.84 (7.02)	−1.452
CES-D	5.51 (4.90)	6.56 (4.99)	−1.986*
WSWS-Anxiety	1.70 (0.86)	1.78 (0.86)	−0.893
WSWS-Sadness	0.99 (0.65)	1.09 (0.65)	−1.434
WSWS-Urge	2.40 (0.77)	2.49 (0.80)	−1.070
WISDM-Craving	4.87 (1.22)	5.09 (1.16)	−1.689
WISDM-Negative reinforcement	4.25 (1.30)	4.13 (1.31)	0.807

* $p < .05$

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Table 3

Multilevel model of craving over four days preceding the target quit day.

	Coefficient	Standard Error	t-ratio	p-value	df	Reliability Coefficient
Average	5.963	0.145	41.315	<0.001*	370	0.942
Baseline WSWS-Urge	0.774	0.151	5.115	<0.001*	370	
WISDM-Craving	0.319	0.099	3.228	0.002*	370	
Initial Cessation Failure	0.237	0.247	0.958	0.339	370	
Recent Smoking	0.232	0.108	2.140	0.032*	5,772	--
Initial Cessation Failure	−0.121	0.181	−0.667	0.505	5,772	
10% cigarette reduction	0.077	0.140	0.549	0.583	5,772	
Initial Cessation Failure X 10% cigarette reduction	−0.552	0.247	−2.237	0.025*	5,772	

* $p < .05$

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Table 4

Multilevel model of negative affect over four days preceding the target quit day

	Coefficient	Standard Error	t-ratio	p-value	df	Reliability Coefficient
Average	3.093	0.104	29.733	<0.001 *	368	0.953
FTND	0.080	0.036	2.194	0.029 *	368	
WSWS-Anxiety	0.311	0.125	2.488	0.014 *	368	
WSWS-Sadness	0.361	0.149	2.423	0.016 *	368	
N-PANAS	0.041	0.016	2.598	0.010 *	368	
Initial Cessation Failure	0.160	0.177	0.901	0.368	368	
Slope	0.126	0.016	7.793	<0.001 *	5,766	--
Age	0.004	0.001	4.006	<0.001 *	5,766	
Baseline WSWS-Anxiety	0.085	0.019	4.472	<0.001 *	5,766	
Baseline WSWS-Sadness	−0.055	0.025	−2.244	0.025 *	5,766	
Initial Cessation Failure	−0.078	0.027	−2.868	0.005 *	5,766	
Recent Smoking	−0.097	0.051	−1.901	0.057	5,766	--
FTND	−0.092	0.018	−5.006	<0.001 *	5,766	
Initial Cessation Failure	0.152	0.090	1.694	0.090	5,766	

* $p < .05$

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