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Repeated measures latent class analysis of daily smoking in three smoking cessation studies

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ABSTRACT

Background: Person-centered approaches to the study of behavior change, such as repeated measures latent class analysis (RMLCA), can be used to identify patterns of change and link these to later behavior change outcomes.
Methods: Daily smoking status data from three smoking cessation studies (N = 287, N = 334, and N = 403) were submitted to RMLCA to identify latent classes of smokers based on patterns of abstinence across the first 27 days of a quit attempt. Three-month biochemically verified abstinence rates were compared among latent classes with particular patterns of smoking across days. Pharmacotherapy variables and baseline individual differences were added as covariates of latent class membership.
Results: Results of separate and pooled analyses supported a five-class solution that replicated across studies. Latent classes included a large class that achieved immediate stable abstinence, a smaller class of cessation failures, and three classes with partial abstinence that increased, decreased, or remained stable over time. Three-month point-prevalence abstinence rates varied among the latent classes, with 38–55% abstinent among early quitters, 3–20% abstinent among those who smoked intermittently throughout the first 27 days, and fewer than 5% abstinent in the classes marked by little or delayed change in smoking. High-dose nicotine patch and bupropion promoted membership in abstinent classes. Demographics, nicotine dependence, and craving were related to latent class in multiple studies and pooled analyses.
Conclusions: We identified five patterns of smoking behavior in the first weeks of a smoking cessation attempt. These patterns are robust across multiple studies and are related to later point-prevalence abstinence rates.

1. Introduction

1.1. Person-centered approaches to the study of relapse

As with many drugs of abuse, relapse remains the most common outcome of attempts to quit smoking (Fiore et al., 2008). Success in quitting is typically measured in binary terms and at discrete time-points (Hughes et al., 2003). This approach is useful in assessing the health impact of smoking cessation treatments, but masks the pathways by which individuals change. Person-centered analysis of abstinence in the first weeks of quitting may reveal meaningful heterogeneity in responses to treatment and aid in identifying risk and protective factors associated with different paths to abstinence or relapse to smoking.

1.2. Modeling change

Relapse has long been recognized as a nonlinear process (Brandon et al., 2007; Shiffman, 1989) requiring nonlinear analytical approaches. In a recent effort to describe patterns of abstinence during a smoking cessation attempt, a repeated measures latent class analysis (RMLCA) of daily smoking in 1433 adult smokers from a trial of five active pharmacotherapies and placebo medication (Piper et al., 2009) yielded five latent classes (McCarthy et al., 2015). The most common patterns were stable success or failure in quitting. Less common patterns indicated unstable patterns of

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behavior during the first 27-days post-quit, with some establishing initially high probabilities of abstinence and then relapsing, others reducing the frequency of smoking early in the quit attempt, and others reporting initial smoking but then markedly increasing abstinence. The latent classes differed in six-month abstinence rates, suggesting that monitoring early smoking patterns may help identify individuals at high risk of longer-term smoking.

1.2.1. Treatment effects on change processes. Modeling change patterns may facilitate treatment evaluation and refinement. Comparing treatments based on their ability to promote early change patterns may tell us more than will the evaluation of distal outcomes. This process approach may also suggest ways to identify individuals who do not initially respond to treatment and who may benefit from adaptive interventions (Rose and Behm, 2014).

1.2.1. Risk and protective factors. Although most smokers who attempt to quit smoking will ultimately relapse, this homogeneity of the distal outcome (relapse) masks considerable heterogeneity of the smoking relapse process (McCarthy et al., 2006). Identifying stable risk and protective factors associated with particular change processes may foster development of treatment-matching protocols to boost cessation success (Witkiewitz et al., 2010). An RMLCA (McCarthy et al., 2015) showed that latent classes of smokers differed in nicotine dependence, smoking history, initial quitting confidence, sleep problems, and ethnic identification. It is important to replicate such findings to identify candidate variables for inclusion in treatment algorithms.

1.3. Study aims

The current study aims to replicate our previous analysis (McCarthy et al., 2015) in three independent smoking cessation studies (Shiffman et al., 1996, 1997; McCarthy et al., 2008a,b) and extend it to new treatment conditions. All studies offered treatment (counseling, patch, and/or bupropion) to smokers motivated to quit and assessed smoking status both in real time using ecological momentary assessment (EMA; Stone and Shiffman, 1994) *via* palmtop computer, and frequent time-line follow-back (TLFB) assessments. Daily abstinence status in the first 27 days of a quit attempt was analyzed using RMLCA to identify the latent classes of abstinence patterns in each study. Analyses addressed relations between 3-month outcomes, treatments, and relapse-relevant covariates and latent class.

Based on results from the six-arm pharmacotherapy trial (McCarthy et al., 2015), we hypothesized that high-dose nicotine patch treatment would facilitate early quitting, whereas bupropion would support recovery from early smoking. Based on an earlier study of counseling effects on lapse reactions (McCarthy et al., 2010), we expected counseling to promote recovery pattern. We also hypothesized that known relapse risk factors including gender, racial minority status, nicotine dependence, quitting confidence, and baseline craving and affective distress would be associated with membership in latent abstinence classes across studies, but did not make *a priori* hypotheses about cross-study variation in these relations.

2. Methods

The design and sample characteristics of each of the three studies are summarized in Tables 1 and 2. Each of these studies has been

Table 1
Summary of study design, sample sizes, and inclusion and exclusion criteria by study.

Study design	Study 1 ($N = 287$) Prospective longitudinal study	Study 2 ($N = 334$) Randomized, double-blind nicotine patch	Study 3 ($N = 407$) Randomized, crossed factorial
Treatments	Group CBT[a]	Patch[b], Group CBT[c]	Bupropion[d], Counseling[e]
Days of EMA: pre-quit/post-quit	16/26	14/56	14/28
Number of clinic visits	8	11	11
Number of counseling sessions	8	7	8
Payment ($)	50	150	200
Distal 7-day abstinence outcome(weeks post-quit)	6–16	11	12
Biochemical validation: CO ppm/cotinine ng/ml	≤8/ < 15	≤8/ < 15	≤10/ < 15
Inclusion Criteria			
Age (years)	≥18	≥21 and ≤65	≥18
Years of smoking	≥2	≥5	
Cigarettes/day	≥10	≥15	≥10
Baseline CO (ppm)			≥10
Exclusion Criteria	Study 1	Study 2	Study 3
Use of other tobacco		X	X
Other drug or alcohol abuse		X	X
Contraindications to nicotine patch		X	
Recent bupropion treatment		X	
Body weight <110 lbs.		X	
Using mood-altering/sedating meds		X	
Reversed/shifted wake-sleep cycle		X	
Serious lung disease		X	
Participation in another study		X	X
Pregnancy or breast feeding		X	X
Living with an enrolled participant		X	X
History of bipolar or psychosis		X	X
Current depression			X
Contraindications to bupropion use			X

[a] 8 60-min group sessions of cognitive behavior therapy for smoking cessation.
[b] Participants were randomly assigned to wear either 35 mg for 3 weeks, 21 mg for 2 weeks, and placebo for 1 week or placebo patches daily for six weeks post-quit.
[c] All participants were encouraged to attend 7 60-min group sessions of cognitive behavior therapy for smoking cessation.
[d] Participants were randomly assigned to take active bupropion SR (150 mg for 4 days then 300 mg for 59 days) or placebo pills (63 days) beginning one week pre-quit.
[e] Participants were randomly assigned to receive 8 individual, face-to-face 10-min smoking cessation counseling sessions or no counseling.

Table 2
Sample characteristics and covariate values in all three studies and the pooled sample.

	Study 1 (*N* = 287)		Study 2 (*N* = 334)		Study 3 (*N* = 407)		Pooled (*N* = 1028)	
Covariate	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age in years	42.4	10.0	39.5	9.4	39.0	12	40.1	10.7
Years of education[a]	9.3	3.8	8.9	3.8	13.9	1.7	11.0	4.0
FTND[b]	5.9	2.2	6.5	2.0	5.0	2.3	3.7	3.2
Cigarettes per day	27.0	11.6	24.1	8.9	21.7	10.4	24.0	10.5
Years Smoked	22.9	12.1	22.1	9.6	21.2	11.3	22.0	11.0
No. past quit attempts	2.5	3.1	4.0	4.4	5.6	10.7	4.2	7.6
Most days abstinent	330.2	665.4	97.9	90.9	116.2	137.2	167.9	368.9
Pre-quit self-efficacy[c]	4.0	0.8	8.9	1.6	1.5	0.9	4.6	3.4
Pre-quit craving[d]	5.4	2.0	7.6	1.3	5.8	2.1	6.4	2.1
Pre-quit sleep[e]	2.1	0.3	5.7	0.5	5.2	0.9	4.7	1.5
Pre-quit negative affect[f]	−0.1	0.5	0.1	0.7	3.2	1.5	1.3	1.9
Pre-quit positive affect[g]			0.1	0.7	7.4	2.0		
Pre-quit CES-D-brief form[h]	1.5	0.5	1.9	1.2	0.2	0.4	1.1	1.1
Pre-quit low arousal[i]	0.0	0.5	0.1	0.5				
Pre-quit inattention[j]	−0.1	0.6	2.6	1.3				
STAI[k]	1.9	0.5						
STAS[l]	3.0	2.3						
Demographics	n	%	n	%	n	%	n	%
Gender (% Female)	122	42.2%	162	48.5%	204	50.1%	486	47.3%
Race								
White	262	91.3%	284	85.0%	363	89.2%	909	88.4%
African American	19	6.6%	37	11.1%	22	5.4%	78	7.6%
Other	3	1.0%	12	3.6%	14	3.4%	29	2.8%
Hispanic	3	1.0%	1	0.3%	8	2.0%	12	1.2%

[a] Education was a categorical variable transformed into a count of years of education by assigning the value at the midpoint of the range in the category selected (*e.g.*, assigning those who said they had some college but did not earn a college degree a value of 14) years.
[b] FTND = Fagerström Test of Nicotine Dependence (Heatherton et al., 1991).
[c] In Studies 1 and 2, this is the mean of pre-quit EMA responses to "Confident in ability to abstain?" (on a 1–4 scale in Study 1, and on a 1–11 scale in Study 2 where 1 = "NO!!" and 4/11 = "YES!!"). In Study 3, this was assessed with a baseline item "If you try to quit smoking within the next 30 days, how likely is it that you will be successful?" on a 7-point scale where 1 = "Very successful" and 7 = "Not at all successful".
[d] In Studies 1 and 2, this is the mean of ratings of "Cigarette Craving" (rated on 1–4 scale in Study 1, and on 1–11 scale in Study 2). In Study 3, this is the pre-quit mean of ratings of "Urge(s) to smoke?" and "Bothered by desire to smoke?" rated 1–11 as in Study 2.
[e] In Studies 1 and 2, this is the pre-quit mean of morning EMA items: "Trouble falling asleep?", "Do you feel well rested?" (reverse coded), "Number of wakenings?", "Rate how well you slept" (from "very well" to "not well at all"), and "Do you feel tired?" rated on 4-point scales in Study 1 and 10-point scales in Study 2 (except for number awakenings which was entered as 0–99). In Study 3, this was the pre-quit morning EMA mean of "Right now-Well rested?" and "Last night-Trouble falling asleep?" ratings rated on 1–11 scales.
[f] In Studies 1 and 2, this is the pre-quit factor score for the following items: ("How feeling? Happy", "irritable", "miserable", "tense", "contented", "frustrated/angry", "sad", and "overall feeling") (see Shiffman et al., 1996 for details). In Study 3, this is the mean of EMA random prompt items "Tense or anxious?" and "Sad or depressed?" rated on a 11-point scale.
[g] In Study 2, this is a factor score defined by happy, contented, calm, and overall feeling items rated on a 11-point scale. In Study 3, this is the mean of PANAS items "Enthusiastic" and "Interested." rated on 11-point scales.
[h] Mean of pre-quit responses to items from the Center for Epidemiologic Studies-Depression (CES-D) Scale (Radloff, 1977): "Have you felt depressed?", "Have you felt lonely?", and "Felt you could not shake off the blues?" rated *via* EMA in Studies 1 (on a 4-point scale) and 2 (11-point scale) and *via* pen-and-paper questionnaire in Study 3 (4-point scale).
[i] Low arousal was assessed by taking the factor score on an factor defined by items "Tired" and "Sleepy" rated on a 4-point scale in Study 1 and 11-point scale in Study 2.
[j] Attention problems were assessed by taking the factor score defined by items "Spacey" and "Hard to concentrate" rated on a 4-point scale in Study 1 and 11-point scale in Study 2.
[k] STAI = Spielberger State-Trait Anxiety Inventory (Spielberger et al., 1983).
[l] STAS = Spielberger State Anger Scale (Spielberger et al., 1986).

described previously (*e.g.*, Study 1: Shiffman et al., 1996; Study 2: Shiffman et al., 2006; Study 3: McCarthy et al., 2008a,b). All three studies provided: treatment to adult daily smokers motivated to quit smoking at no-cost, compensation for participation, and palm-top computers to record experiences and behaviors up to nine times per day. In all three studies, latent class membership was defined based on daily smoking status indicators collected *via* EMA (when available) or TLFB data on daily smoking. All three studies assessed biochemically verified seven-day point-prevalence abstinence between 2.5 and 4 months post-quit.

2.1. Data analysis

We examined the number and correlates of latent classes that emerged based on daily smoking status in the first 27 days of a quit attempt. The RMLCA approach was adopted to capture time-dependent patterns rather than to estimate probabilities of transitions among latent states, as in hidden Markov models (Killeen, 2011). In addition, RMLCA examines latent smoking patterns without imposing restrictions of patterns across time, whereas hidden Markov models impose autoregressive effects of time where the current state is dependent on prior states.

We conducted both separate and pooled analyses, beginning first with unconditional models and then adding distal outcomes, treatment variables, and standardized covariates. All models assume conditional independence of the daily smoking data (*i.e.*, that all covariation in daily smoking status is fully accounted for by the latent class). Models were estimated using SAS 9.3 (SAS Institute Inc., Cary, NC) *via* Proc LCA using maximum likelihood estimation with 200 random starts.

2.1.1. Unconditional models. Unconditional models with 1–8 classes were fit to each separate study and to pooled data across studies to identify the optimal number of latent classes based on: interpretability, Bayesian Information Criteria (BIC; Nylund et al., 2006; Schwarz, 1978), BIC adjusted for sample size (aBIC,

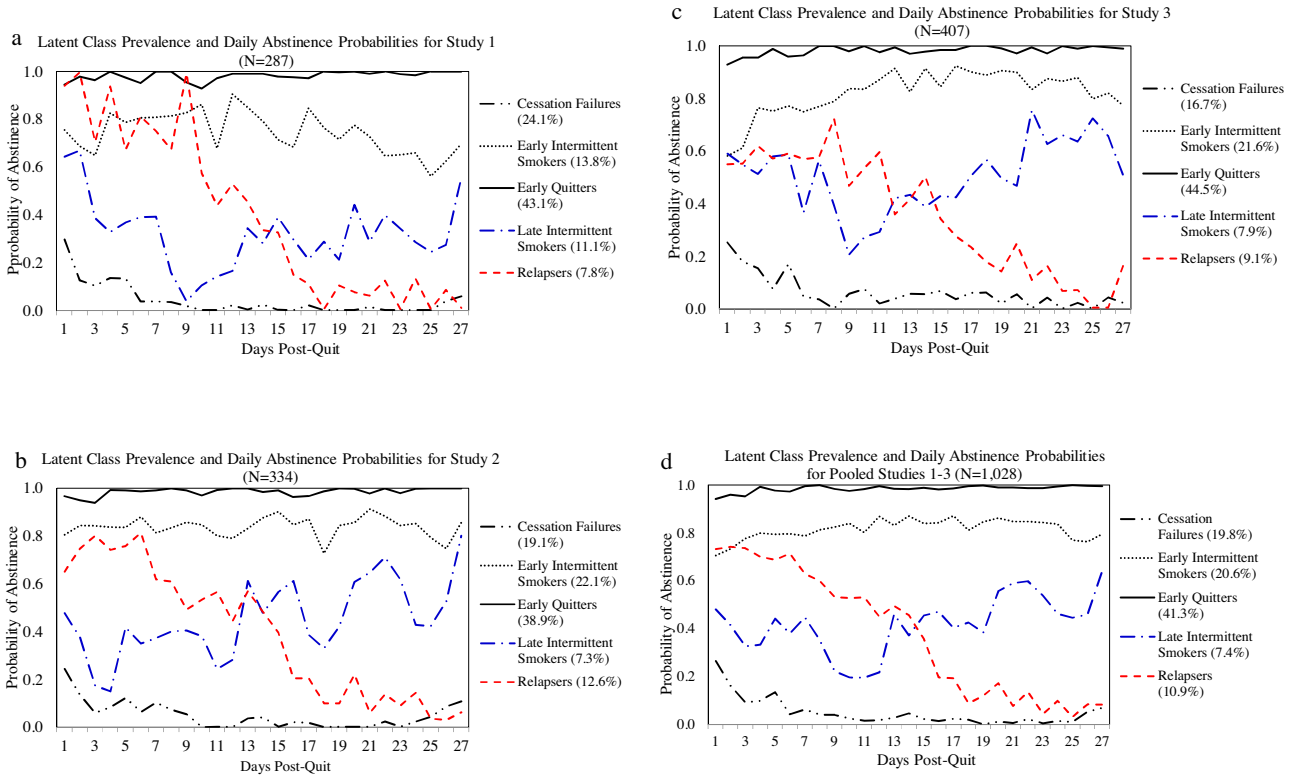

Fig. 1. Estimated probability of abstinence from cigarettes by day for the first 27 days of a quit attempt by latent class in Study 1 (panel A), Study 2 (panel B), Study 3 (panel C), and the pooled analysis of Studies 1–3 (panel D). Percentage following each class indicates prevalence of the class.

Sclove, 1987), bootstrapped likelihood ratio test (BLRT, a measure of improvement in model fit with each additional class; McLachlan and Peel, 2000; Nylund et al., 2006), and model entropy (a measure of classification precision).

2.1.2. Distal outcomes. Distal abstinence outcome (biochemically confirmed point-prevalence abstinence 2.5–4 months post-quit) associations with latent class membership were examined by computing the marginal means of abstinence (0 = smoking, 1 = abstinence) in each class in each study and in a pooled dataset. Individuals cannot be assigned to latent classes with certainty, but each individual is assigned a posterior probability of membership in each class and these can be used to identify the class to which individuals most likely belong.

2.1.3. Treatment. Treatment was coded using a dummy variable (0 = placebo, 1 = active patch) in Study 2. In Study 3, three dummy indicators were included to capture the effect of each active treatment (counseling alone, bupropion SR alone, or the combination of counseling and bupropion SR) relative to the no counseling, placebo control group.

2.1.4. Covariates. Covariates were added to explore correlates of latent class membership and to estimate treatment effects on latent class membership (in Studies 2–3). Single covariate models were run first to determine whether each candidate predicted class membership at $p < 0.20$. Those that did were included in multivariate models. Only covariates that reached significance in stepwise multivariate models (the two predictors with the lowest p values were added, followed by others in ascending order by univariate p value) were retained in the final model. All continuous covariates were standardized within-study. Missing data are not permitted for covariates in RMLCA and there is not yet a program available to reconcile RMLCA results across multiple imputed datasets. As such, some cases [22 (7.7%) in Study 1, 2 (0.6%) in Study 2, 1 (0.2%) in Study 3, 52 (5.1%) in the pooled analysis] were lost in the conditional models.

3. Results

3.1. Unconditional models

Based on an examination of fit indices, model rho parameters (daily abstinence probabilities within classes), and gamma parameters (latent class prevalences), we retained a 5-class model in all three studies and a pooled analysis (Table 3). Fig. 1a–c display the daily abstinence probabilities and prevalences by latent class for each study and Fig. 1d shows the pooled results. As in McCarthy et al. (2015), we have labeled the classes *Early Quitters* for those who maintain a high probability of abstinence, *Cessation Failures* for those with near-zero abstinence probabilities, *Early Intermittent Smokers* for those with intermediate abstinence probabilities, *Late Intermittent Smokers* for those with initially low abstinence probabilities that increase over days, and *Relapsers* for those with initially high abstinence probabilities that decline over days. A test of invariance across studies indicated that model fit improved when latent class prevalence and rho parameters were allowed to vary across studies ($\Delta G^2 = 344.55$, $df = 270$, $p = 0.0014$), although the nature of the latent classes was strikingly similar across studies (see Fig. 1a–c). Tests of invariance are sensitive to minor variations in rho parameters (the analysis considers each day as a separate variable, with no concept of time sequence or adjacency, so even a one-day shift in a smoking transition may appear as a major discrepancy). As an alternative approach to assessing the similarity of the latent class solution across studies, we examined the concordance between assignment of participants to latent classes in the separate versus pooled models. We found a very high rate of con-

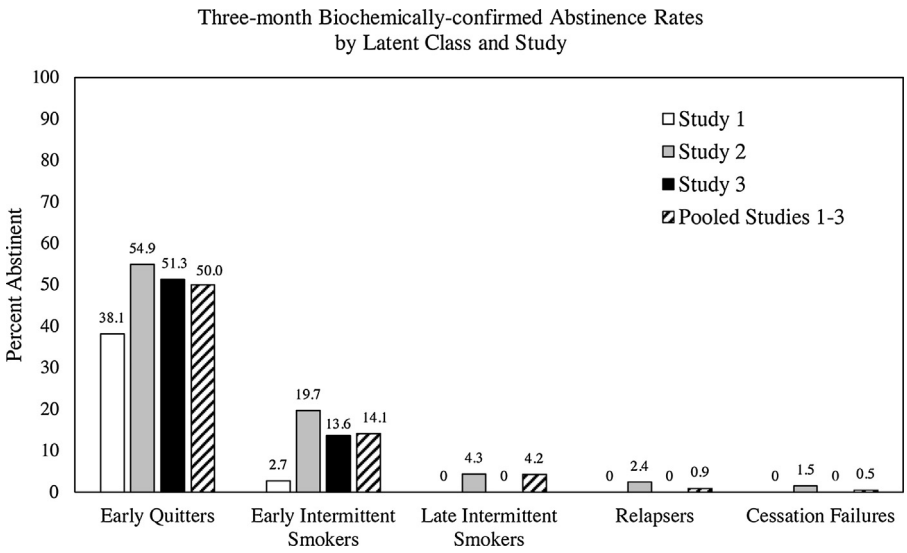

Fig. 2. Marginal abstinence rates at approximately three months post-target-quit-day by latent class (with participants assigned to a class based on posterior probabilities of membership in each class) by Study. Abstinence was determined by self-report of no smoking in the past seven days at a follow-up interview conducted 2.5–4 months post-quit and by carbon monoxide and cotinine.

Table 3
Pooled and separate model fit indices for unconditional models with 3–6 classes.

Latent Classes	Log-likelihood	df	BIC	BIC Δ	aBIC	aBIC Δ	Entropy	BLRT
Study 1								
3	−2011	134,217,644	2267	382	2003	471	0.97	<0.001
4	−1915	134,217,616	2235	32	1883	121	0.94	<0.001
5	−1852	134,217,588	2266	−32	1825	57	0.95	<0.001
6	−1805	134,217,560	2331	−65	1801	24	0.95	<0.001
Study 2								
3	−2865	134,217,644	3489	424	3225	513	0.96	<0.001
4	−2747	134,217,616	3414	74	3062	163	0.93	<0.001
5	−2665	134,217,588	3413	1	2972	90	0.93	<0.001
6	−2610	134,217,560	3466	−53	2936	36	0.93	<0.001
Study 3								<0.001
3	−3184	134,217,644	3585	447	3321	536	0.9	<0.001
4	−3086	134,217,616	3557	28	3205	117	0.87	<0.001
5	−3037	134,217,588	3626	−68	3185	20	0.87	<0.001
6	−2996	134,217,560	3712	−86	3182	3	0.86	<0.001
Pooled Analysis: Studies 1–3								
3	−8489	134,217,644	7686	1445	7423	1533	0.93	$p < 0.001$
4	−7886	134,217,616	7275	411	6923	500	0.90	$p < 0.001$
5	−7735	134,217,588	7167	108	6726	197	0.89	$p < 0.001$
6	−7638	134,217,560	7167	0	6636	90	0.88	$p < 0.001$

BIC is the Bayesian information criterion, a measure of model fit; smaller values indicated better fit. aBIC is the BIC adjusted for sample size; smaller values again indicate better fit. Entropy is a measure of the accuracy of classification of participants in latent classes and of class differentiation; higher values indicate better classification. BLRT is the Bootstrap likelihood ratio test, a test of the significance of differences in model fit with the addition of one more latent class; $p < 0.05$ indicates a significant change in model fit with a change in the number of latent classes.

cordance (*kappa* = 0.96), confirming the consistency of the latent class solutions across studies.

3.2. Distal outcomes

Confirmed abstinence rates 2.5–4 months post-quit are shown by latent class and study in Fig. 2. Only the *Early Quitter* class had a substantial abstinence rate (38.1%) in Study 1. In Studies 2 and 3, greater than 50% of *Early Quitters* and nearly 14% (Study 3) and 20% (Study 2) of *Early Intermittent Smokers* were abstinent three-months post-quit. Abstinence rates were below 5% in all other classes. In the pooled analysis, *Early Quitters* had significantly higher abstinence rates than all other classes (all *ps* < = 0.001). *Early Intermittent Smokers* had significantly higher abstinence rates than did *Relapsers* ($p = 0.008$) or *Cessation Failures* ($p < 0.001$). *Late Intermittent Smokers* also had significantly higher abstinence rates than did *Cessation Failures* ($p = 0.03$).

3.3. Treatment effects in Studies 2 and 3

Table 4 shows treatment effects on latent class membership in the full final conditional models (*i.e.*, adjusted for the covariates listed in Table 5) for Studies 2 and 3. In Study 2, High-dose patch treatment significantly reduced the odds of being in all transient change classes (*Cessation Failure*, *Relapse*, and *Late Intermittent Smoking*) compared to *Early Quitting* (Table 4A). Active patch treatment also significantly increased the odds of membership in all change classes compared to *Cessation Failure* (Table 4B) and increased the odds of sustained *Early Intermittent Smoking* rather

Table 4
Odds ratios with 95% Confidence Interval [CI] of latent class membership treatment variables by study.

Study	Treatment	Early Intermittent	Late Intermittent	Relapse	Cessation Failure
Panel A: Comparison to Early Quitter Class					
2	Nicotine patch	0.94 [0.57, 1.56]	**0.50 [0.26, 0.97]***	**0.41 [0.24, 0.68]***	**0.11 [0.07, 0.20]***
3	Bupropion SR and counseling	0.73 [0.40, 1.34]	**0.35 [0.17, 0.71]***	0.56 [0.22, 1.43]	**0.16 [0.08, 0.33]***
	Bupropion SR alone	**0.48 [0.25, 0.91]***	**0.52 [0.27, 0.98]***	0.92 [0.40, 2.16]	**0.23 [0.13, 0.43]***
	Counseling alone	0.82 [0.43, 1.57]	0.88 [0.47, 1.66]	1.00 [0.41, 2.45]	0.58 [0.33, 1.03]
Panel B: Comparison to Cessation Failure Class					
2	Nicotine patch	**8.24 [4.49, 15.13]***	**4.37 [2.03, 9.40]***	**3.55 [1.88, 6.70]***	
3	Bupropion SR and counseling	**4.44 [2.05, 9.61]***	2.13 [0.91, 4.98]	**3.42 [1.19, 9.88]***	
	Bupropion SR alone	2.03 [0.97, 4.21]	**2.20 [1.07, 4.53]***	**3.94 [1.56, 9.97]***	
	Counseling alone	1.41 [0.72, 2.75]	1.51 [0.78, 2.92]	1.72 [0.68, 4.35]	
Panel C: Comparison to Relapse Class					
2	Nicotine patch	**2.32 [1.28, 4.22]***	1.23 [0.57, 2.65]		
3	Bupropion SR and counseling	1.30 [0.48, 3.54]	0.62 [0.21, 1.84]		
	Bupropion SR alone	0.51 [0.20, 1.33]	0.56 [0.22, 1.45]		
	Counseling alone	0.82 [0.31, 2.17]	0.88 [0.33, 2.34]		
Panel D: Comparison to Late Intermittent Smoker Class					
2	Nicotine patch	1.89 [0.91, 3.94]			
3	Bupropion SR and counseling	2.09 [0.94, 4.64]			
	Bupropion SR alone	0.92 [0.42, 1.99]			
	Counseling alone	0.94 [0.44, 1.98]			

* Bolded values are significant at $p < 0.05$.

than *Relapse* (Table 4C). Patch treatment did not differentiate *Early* and *Late Intermittent Smokers* (Table 4D).

In Study 3, relative to the placebo no counseling condition, active bupropion reduced the odds of early smoking (as shown by lower odds of *Cessation Failure* and *Intermittent Smoking* versus *Early Quitting*), and increased odds of *Relapse* versus *Cessation Failure*. These effects generally held with or without counseling, although the effect on *Early Intermittent Smoking* versus *Cessation Failure* was only significant with counseling, and the effect on *Early Intermittent Smoking* versus *Early Quitting* was only significant in the absence of counseling. Bupropion SR also promoted recovery from early smoking (*Late Intermittent Smoking* versus *Cessation Failure*), but this was only significant in the absence of counseling. No treatment differentiated *Early* and *Late Intermittent Smokers* (Table 4D). Counseling alone had no significant effects.

3.4. Conditional models (with covariates)

Covariates that significantly correlate with the likelihood of class-membership in a multivariate multinomial logistic regression model are indicated in Table 5. For each covariate in the final model, a panel of Table 5 depicts the odds ratio of membership in a particular class, relative to a specified reference class. Results for each study and the pooled analyses are shown by row. Covariates that were not significantly related to latent class in any study (pre-quit self-efficacy, affect, sleep disturbance, and depressive symptoms) were dropped from the final models and are not shown.

3.4.1. Gender. Estimated odds ratios (Table 5A.) were significantly above one in the contrast of all early smoking classes (*Cessation Failures* and both *Early* and *Late Intermittent Smokers*) *vs*. *Early Quitters* in all but Study 1, indicating that women were more likely than men to continue smoking at the outset of the quit attempt in studies 2, 3, and the pooled analyses. Women were significantly more likely to *Relapse* than to be *Early Quitters* only in the pooled analyses, perhaps due to the small numbers of *Relapsers* in individual studies. In Study 1 only, women were significantly more likely than men to engage in *Early Intermittent Smoking* rather than daily smoking (*Cessation Failure*). In Study 2 only, women were more likely than men to be *Late Intermittent Smokers* relative to all other classes.

3.4.2. Minority status. Relations between minority status and latent class (Table 5B) suggested greater risk of membership in a smoking class than the *Early Quitter* class in all but Study 1. In Study 2, members of minority racial/ethnic groups were twice as likely to be *Cessation Failures* and four times as likely to be *Late Intermittent Smokers* than *Early Quitters*, relative to White participants. In Study 3 and the pooled analyses, minority participants were more likely than White participants to be *Early Intermittent Smokers* than *Early Quitters*. Minority status was related to greater odds of recovery (*Late Intermittent Smoking*) versus *Relapse* than *Early Intermittent Smoking* only in better powered, pooled analyses.

3.4.3. Baseline cigarettes per day. The direction of relations between smoking heaviness and latent abstinence class was largely consistent across studies (Table 5C), despite differences in the magnitude and statistical significance of these effects. Greater smoking heaviness was associated with increased odds of being in higher risk classes rather than the *Early Quitting* class; in Study 1 and the pooled analyses, greater smoking heaviness was associated with increased odds of *Cessation Failure*; in Study 2 and the pooled analyses, heavier smoking predicted increased odds of *Relapse* and *Early Intermittent Smoking*. These effects were more modest in Study 3 and did not reach significance.

3.4.4. Baseline FTND. Scores on the FTND (Table 5D) were associated with increased risk of initial difficulty quitting in some studies (*Late Intermittent Smoking* in Study 1 and pooled analyses and *Cessation Failure* in pooled analyses). Study 3 suggested an unexpected associated between greater dependence and reduced risk of *Relapse* following cessation (*Early Quitting*), but this did not replicate across studies. In Study 3 and the pooled analyses, greater dependence was associated with reduced odds of early, partial change in smoking (*Early Intermittent Smoking* or *Relapse*) relative to *Cessation Failure*. More dependent individuals were more likely to be *Late Intermittent Smokers vs*. *Relapsers* in Study 1 and the pooled analyses (with similar but non-significant odds ratios in Studies 2 and 3), which may reflect a relation between dependence and difficulty achieving initial abstinence. Greater dependence was associated with lower odds of recovering toward abstinence over days, versus *Early Intermittent Smoking* across studies; this was significant in Studies 1 and pooled analyses.

Table 5
Odds ratios with 95% Confidence Interval [CI] of latent class membership by covariate and study.

Panel A. Gender (1 = Female, 0 = Male)

	Study	Early Intermittent	Late Intermittent	Relapse	Cessation Failure
Comparison to Early Quitter Class	1	0.90 [0.47, 1.71]	1.07 [0.56, 2.06]	1.15 [0.54, 2.43]	1.76 [0.98, 3.15]
	2	**2.11 [1.25, 3.57]***	**5.88 [2.38, 14.51]***	1.33 [0.73, 2.40]	**1.78 [1.05, 3.00]***
	3	**1.55 [1.00, 2.42]***	**2.66 [1.65, 4.28]***	1.61 [0.87, 30.00]	**2.32 [1.47, 3.65]***
	Pooled	**1.46 [1.11, 1.93]***	**2.13 [1.41, 3.22]***	**1.54 [1.10, 2.17]***	**1.80 [1.36, 2.39]***
Comparison to Cessation Failure Class	1	**2.79 [1.08, 7.22]***	0.84 [0.46, 1.55]	0.63 [0.32, 1.22]	
	2	1.19 [0.65, 2.18]	**3.31 [1.27, 8.59]***	0.75 [0.38, 1.46]	
	3	0.67 [0.40, 1.13]	1.15 [0.66, 1.99]	0.70 [0.35, 1.40]	
	Pooled	0.81 [0.59, 1.12]	1.19 [0.76, 1.85]	0.86 [0.59, 1.25]	
Comparison to Relapse Class	1	0.78 [0.34, 1.83]	0.94 [0.39, 2.23]		
	2	1.59 [0.82, 3.10]	**4.44 [1.64, 12.01]***		
	3	0.96 [0.49, 1.90]	1.65 [0.81, 3.36]		
	Pooled	0.95 [0.65, 1.38]	1.38 [0.85, 2.26]		
Comparison to Late Intermittent Smoker Class	1	0.84 [0.39, 1.77]			
	2	**0.36 [0.14, 0.93]***			
	3	0.58 [0.33, 1.02]			
	Pooled	0.69 [0.44, 1.07]			

Panel B. Minority (1 = Minority, 0 = White)

	Study	Early Intermittent	Late Intermittent	Relapse	Cessation Failure
Comparison to Early Quitter Class	1	0.09 [0.00, 2.02]	1.96 [0.68, 5.65]	0.63 [0.14, 2.85]	1.02 [0.35, 3.02]
	2	2.13 [0.98, 4.62]	**4.21 [1.63, 10.89]***	1.77 [0.73, 4.27]	**2.42 [1.16, 5.07]***
	3	**2.64 [1.44, 4.87]***	1.09 [0.47, 2.53]	0.84 [0.26, 2.69]	1.39 [0.65, 2.95]
	Pooled	**1.55 [1.01, 2.37]***	**2.33 [1.34, 4.06]***	1.01 [0.56, 1.84]	1.40 [0.88, 2.23]
Comparison to Cessation Failure Class	1	1.98 [0.72, 5.42]	1.14 [0.50, 2.59]	0.83 [0.32, 2.16]	
	2	0.88 [0.39, 2.00]	1.74 [0.65, 4.67]	0.73 [0.29, 1.87]	
	3	1.91 [0.88, 4.15]	0.78 [0.30, 2.07]	0.61 [0.17, 2.22]	
	Pooled	1.10 [0.67, 1.81]	1.66 [0.90, 3.06]	0.72 [0.37, 1.39]	
Comparison to Relapse Class	1	0.14 [0.00, 4.19]	3.11 [0.61, 15.91]		
	2	1.20 [0.46, 3.12]	2.38 [0.79, 7.22]		
	3	3.15 [0.97, 10.25]	1.29 [0.34, 4.87]		
	Pooled	1.53 [0.82, 2.86]	**2.31 [1.12, 4.78]***		
Comparison to Late Intermittent Smoker Class	1	0.05 [0.00, 1.08]			
	2	0.50 [0.18, 1.38]			
	3	2.43 [0.99, 5.99]			
	Pooled	0.66 [0.37, 1.19]			

Panel C. Baseline cigarettes/day

	Study	Early Intermittent	Late Intermittent	Relapse	Cessation Failure
Comparison to Early Quitter Class	1	1.26 [0.85, 1.86]	0.97 [0.63, 1.48]	1.43 [0.96, 2.13]	**1.66 [1.19, 2.30]***
	2	**2.04 [1.42, 2.93]***	1.23 [0.68, 2.21]	**1.67 [1.11, 2.50]***	1.39 [0.95, 2.03]
	3	1.03 [0.78, 1.36]	0.85 [0.61, 1.18]	1.14 [0.78, 1.67]	1.16 [0.89, 1.51]
	Pooled	**1.23 [1.05, 1.44]***	1.06 [0.84, 1.35]	**1.39 [1.16, 1.66]***	**1.32 [1.13, 1.53]***
Comparison to Cessation Failure Class	1	0.60 [0.33, 1.09]	0.68 [0.46, 1.01]	0.82 [0.54, 1.23]	
	2	1.47 [0.99, 2.18]	0.89 [0.48, 1.63]	1.20 [0.77, 1.87]	
	3	0.89 [0.67, 1.17]	0.74 [0.52, 1.03]	0.98 [0.66, 1.45]	
	Pooled	0.94 [0.80, 1.10]	0.81 [0.63, 1.03]	1.05 [0.88, 1.27]	
Comparison to Relapse Class	1	0.88 [0.57, 1.35]	0.68 [0.42, 1.10]		
	2	1.22 [0.81, 1.85]	0.74 [0.39, 1.38]		
	3	0.90 [0.61, 1.35]	0.75 [0.48, 1.17]		
	Pooled	0.89 [0.74, 1.07]	0.77 [0.59, 1.00]		
Comparison to Late Intermittent Smoker Class	1	1.30 [0.82, 2.06]			
	2	1.66 [0.91, 3.00]			
	3	1.21 [0.85, 1.72]			
	Pooled	1.16 [0.91, 1.48]			

Panel D. Baseline FTND

Covariate	Study	Early Intermittent	Late Intermittent	Relapse	Cessation Failure
Comparison to Early Quitter Class	1	1.04 [0.57, 1.90]	**3.89 [1.95, 7.78]***	0.76 [0.39, 1.46]	1.49 [0.87, 2.54]
	2	1.07 [0.41, 2.82]	2.73 [0.58, 12.73]	1.77 [0.59, 5.27]	2.29 [0.85, 6.18]
	3	0.71 [0.49, 1.04]	1.02 [0.69, 1.53]	**0.58 [0.35, 0.98]***	1.25 [0.86, 1.82]
	Pooled	1.00 [0.86, 1.16]	**1.45 [1.17, 1.81]***	1.02 [0.85, 1.23]	**1.47 [1.26, 1.70]***
Comparison to Cessation Failure Class	1	2.54 [0.49, 13.05]	2.13 [0.68, 6.65]	1.65 [0.49, 5.57]	
	2	0.47 [0.15, 1.47]	1.19 [0.23, 6.25]	0.77 [0.22, 2.75]	
	3	**0.57 [0.37, 0.88]***	0.82 [0.52, 1.29]	**0.47 [0.26, 0.83]***	
	Pooled	**0.68 [0.58, 0.81]***	0.99 [0.79, 1.25]	**0.70 [0.57, 0.85]***	

Table 5 (*Continued*)

Panel D. Baseline FTND

Covariate	Study	Early Intermittent	Late Intermittent	Relapse	Cessation Failure
Comparison to Relapse Class	1	1.38 [0.66, 2.88]	**5.15 [2.23, 11.89]***		
	2	0.61 [0.18, 2.06]	1.54 [0.27, 8.74]		
	3	1.22 [0.69, 2.16]	1.76 [0.97, 3.18]		
	Pooled	0.98 [0.80, 1.19]	**1.42 [1.10, 1.84]***		
Comparison to Late Intermittent Smoker Class	1	**0.27 [0.12, 0.58]***			
	2	0.39 [0.08, 2.02]			
	3	0.70 [0.44, 1.10]			
	Pooled	**0.69 [0.55, 0.87]***			

Panel D. Number of past quit attempts

	Study	Early Intermittent	Late Intermittent	Relapse	Cessation Failure
Comparison to Early Quitter Class	1	0.51 [0.18, 1.43]	0.74 [0.30, 1.82]	**2.23 [1.04, 4.78]***	1.00 [0.46, 2.16]
	2	1.20 [0.82, 1.74]	0.74 [0.35, 1.53]	0.96 [0.59, 1.56]	**0.55 [0.30, 0.99]***
	3	Did not converge	Did not converge	Did not converge	Did not converge
	Pooled	1.06 [0.93, 1.20]	1.08 [0.93, 1.26]	1.10 [0.96, 1.26]	**0.64 [0.48, 0.84]***
Comparison to Cessation Failure Class	1	0.62 [0.29, 1.30]	**0.46 [0.24, 0.85]***	0.80 [0.48, 1.35]	
	2	**2.19 [1.18, 4.09]***	1.35 [0.55, 3.29]	1.76 [0.88, 3.53]	
	3	Did not converge	Did not converge	Did not converge	
	Pooled	**1.66 [1.24, 2.20]***	**1.70 [1.26, 2.29]***	**1.72 [1.28, 2.31]***	
Comparison to Relapse Class	1	**0.23 [0.07, 0.71]***	**0.33 [0.12, 0.92]***		
	2	1.25 [0.74, 2.09]	0.77 [0.34, 1.74]		
	3	Did not converge	Did not converge		
	Pooled	0.96 [0.83, 1.11]	0.99 [0.83, 1.17]		
Comparison to Late Intermittent Smoker Class	1	0.69 [0.21, 2.28]			
	2	1.62 [0.77, 3.43]			
	3	Did not converge			
	Pooled	0.98 [0.83, 1.15]			

Panel F. Baseline EMA craving

	Study	Early Intermittent	Late Intermittent	Relapse	Cessation Failure
Comparison to Early Quitter Class	1	0.72 [0.50, 1.01]	0.77 [0.55, 1.10]	1.15 [0.78, 1.69]	0.89 [0.65, 1.20]
	2	0.82 [0.55, 1.21]	1.58 [0.82, 3.06]	0.85 [0.55, 1.32]	1.10 [0.73, 1.65]
	3	**1.95 [1.53, 2.49]***	**2.32 [1.79, 3.00]***	**1.90 [1.37, 2.64]***	**2.31 [1.81, 2.96]***
	Pooled	**1.18 [1.02, 1.36]***	**1.45 [1.18, 1.79]***	1.18 [0.99, 1.41]	**1.52 [1.31, 1.76]***
Comparison to Cessation Failure Class	1	1.93 [0.96, 3.89]	1.34 [0.84, 2.14]	1.04 [0.63, 1.70]	
	2	0.74 [0.47, 1.18]	1.44 [0.71, 2.91]	0.77 [0.46, 1.29]	
	3	0.84 [0.64, 1.12]	1.00 [0.75, 1.34]	0.82 [0.57, 1.18]	
	Pooled	**0.78 [0.66, 0.91]***	0.96 [0.77, 1.20]	**0.78 [0.64, 0.95]***	
Comparison to Relapse Class	1	**0.62 [0.40, 0.98]***	0.68 [0.43, 1.07]		
	2	0.96 [0.59, 1.58]	1.86 [0.89, 3.88]		
	3	1.03 [0.72, 1.47]	1.22 [0.84, 1.77]		
	Pooled	1.00 [0.82, 1.21]	1.23 [0.96, 1.59]		
Comparison to Late Intermittent Smoker Class	1	0.92 [0.61, 1.39]			
	2	0.52 [0.26, 1.04]			
	3	0.84 [0.63, 1.13]			
	Pooled	0.81 [0.65, 1.01]			

* Bolded values are significant at $p < 0.05$.

3.4.5. Number of past quit attempts. Quitting history was associated with latent class (Table 5E) such that more past quitting was associated with reduced risk of *Cessation Failure* (in Study 2 and the pooled analyses). Past quitting (which by definition involved past relapsing in the smokers enrolled in this trial) was associated with increased odds of *Relapse* (*vs. Early Quitting* in Study 1, *vs. Cessation Failure* in pooled analyses, and *vs. Intermittent Smoking* in Study 1). Results generally suggest an association between past quit attempts and a pattern of *Relapse* in this quit attempt. Study 3 models including number of past quit attempts did not converge.

3.4.6. Baseline EMA craving. Relations between baseline EMA measures of craving (which varied across studies in terms of items and scaling) and latent class (Table 5F) were highly variable across studies. Although baseline craving was significantly associated with greater odds of membership in a smoking class *vs. Early Quitting* in Study 3 and pooled analyses, this was not true in Studies 1 and 2. Greater craving was associated with reduced odds of early, partial change (*Early Intermittent Smoking* or *Relapse*) versus *Cessation Failure* in pooled analyses (reflecting similar but non-significant results in Studies 2 and 3). Baseline craving was greater risk of *Relapse* (versus *Early Intermittent Smoking*) in Study 1 only.

4. Discussion

The current results replicate a previous RMLCA of smoking status in the first 27 days of a quit attempt (McCarthy et al., 2015) and extend knowledge regarding treatment effects on latent abstinence patterns early in the quitting process. Results of three independent studies converged on a five-class solution: early and stable abstinence, stable reduction, early success followed by relapse, early struggle followed by improvement, or failure

to change. Early stable abstinence and reduction are associated with better three-month outcomes. High-dose nicotine patch and bupropion SR appear to promote early abstinence. High-dose patch also appears to promote intermittent smoking, particularly early intermittent smoking, rather than daily smoking. Bupropion SR effects on intermediate classes were dependent on counseling.

4.1. Latent class structure

In every study, the largest class (39–45% of smokers) was marked by stable abstinence (*Early Quitter*), despite the varying sample characteristics and treatments across studies. In all three studies, a smaller group (*Cessation Failure,* 17–24%) failed to quit, as shown by low abstinence probabilities through 27 days post-quit. The remaining three latent classes had intermediate abstinence probabilities. *Early Intermittent Smokers* (14–22%) maintained 0.60–0.90 abstinence probabilities across days. Those in a *Relapse* class (8–13%) established initial abstinence but then returned to consistent smoking. *Late Intermittent Smokers* (7–11%) showed the opposite pattern, with low or unstable abstinence probabilities initially that increased over weeks. These results are highly concordant with the latent class structure that emerged in an RMLCA of a large trial (McCarthy et al., 2015) and the consistency of the classes across studies is striking.

4.2. Distal outcomes

Three-month abstinence rates were highest in the *Early Quitter* latent class, as in McCarthy et al., 2015. In contrast to that study, the only other class with substantial abstinence rates at three months in the present study was the *Early Intermittent Smoker* class. McCarthy et al. (2015) found *Late Intermittent Smokers* achieved an impressive 23% abstinence rate six months post-quit, whereas *Early Intermittent Smokers* had only a 10% abstinence rate. Thus, in the current analyses, recovery from initial struggles among *Late Intermittent Smokers* did not predict later abstinence as in the prior study (McCarthy et al., 2015). Nonetheless, the present results suggest that establishing and maintaining high probabilities of abstinence in the first weeks of a quit attempt marks one for later success.

4.3. Treatment

In Study 2, active high-dose patch with counseling promoted early change (*Early Quitting* and *Early Intermittent Smoking*) and prevented *Cessation Failure*, as hypothesized. High-dose patch also beat our expectations by preventing *Relapse* relative to those with high initial abstinence probabilities (*Early Quitters* and *Early Intermittent Smokers*) and fostering recovery from initial smoking better than did placebo patch. Patch treatment did not differentiate *Late Intermittent Smokers* from those achieving earlier partial change (*Early Intermittent Smoking* or *Relapse*). The lack of effects in comparisons of these smaller, intermediate classes may reflect lower power or may indicate that patch therapy works roughly equally well among these latent classes, despite their different patterns of abstinence.

In Study 3, bupropion SR also appeared to promote early abstinence (*Early Quitting* or *Relapse*) rather than initial smoking (*Cessation Failure* or *Late Intermittent Smoking*). This benefit of bupropion SR was not dependent on counseling. Bupropion SR effects on intermediate classes were dependent on counseling, however. Bupropion SR with counseling significantly increased the odds of early intermittent smoking (partial change) rather than cessation failure, whereas bupropion alone had a more modest and non-significant benefit. Although active medication was associated with increased odds of recovery from initial smoking (versus continued daily smoking) when offered alone, this effect was not augmented by counseling. As such, the hypothesis that bupropion SR would enhance recovery from initial smoking received only partial support and the hypothesis that counseling would foster recovery for early smoking was not supported. Inconsistencies in medication effects across counseling conditions may reflect low power for comparisons among relatively small classes. The direction of medication effects was consistent across counseling conditions, but differed in magnitude and significance. The failure to detect any benefits of counseling with placebo medication is consistent with earlier logistic regression and survival analyses showing no significant benefit of counseling in this trial (McCarthy et al., 2008a).

4.4. Covariates

The final conditional models contained only those covariates that remained significantly related to latent class membership in at least one study.

4.4.1. Gender. In the larger studies (Studies 2 and 3 and the pooled analyses), women were at greater risk of continued smoking after the target quit day than were men. These data are consistent with prior trials of treatments similar to those tested here that suggested women have more difficulty quitting than do men (Fortmann and Killen, 1994; Perkins and Scott, 2008; Scharf and Shiffman, 2004), but not our earlier RMLCA of early smoking in a 6-arm RCT (McCarthy et al., 2015). These effects were weaker and not significant in the smaller group CBT study in which women were more likely than men to show a significant and stable reduction in smoking days, rather than cessation failure. In the high-dose nicotine patch trial, women were three to four times more likely than men to recover over time rather than continue or return to daily smoking, despite suggestions that nicotine replacement is ineffective in women (Perkins, 2001). This did not occur in the group CBT or bupropion SR and counseling trials. Given the differences among studies, it is difficult to determine the reasons for these inconsistencies. Studies at the population level have found age-specific gender differences, such that women are more likely to quit than are men before age 50 or 60, before the pattern reverses in late life, washing out gender differences in analyses collapsed over age (Jarvis et al., 2013). A larger proportion of participants were over age 50 in Study 1 and the McCarthy et al., 2015 study than in Studies 2 and 3 that showed significant gender differences, however. As such, it is not clear why gender was related to smoking class in only some samples or circumstances.

4.4.2. Minority status. Epidemiological data suggest that smoking cessation rates are lower among African-American smokers, despite greater interest in quitting and more quit attempts (Malarcher et al., 2011). The current analyses detected greater odds of early smoking in the high-dose nicotine patch RCT, and evidence of lower odds of quitting completely (*vs.* reducing smoking frequency) in the bupropion SR and counseling RCT among minority (mostly African American) versus non-minority smokers. Similar results were found in our previous RMLCA (McCarthy et al., 2015). When the samples were pooled, there was evidence of greater odds of recovery versus relapse. This effect was in the same direction across all three studies, but only significant when pooled. These data are consistent with both greater difficulty quitting initially and greater motivation to continue trying to quit despite these initial difficulties among minority smokers. The reasons for the inconsistencies across studies are not clear. Research with enriched sampling of specific racial or ethnic subpopulations is needed to resolve these discrepancies across studies.

4.4.3. Nicotine dependence. Results indicated that cigarettes per day, FTND scores, and the number of past quit attempts were significantly related to less favorable latent smoking classes. The patterns of covariate relations with class contrasts varied across studies, but generally supported a relation between greater dependence and greater risk of smoking. Heavier smokers were less likely to be *Early Quitters* than in a smoking class in two of the three studies. In pooled analyses, higher scores on the FTND were also related to lower odds of sustained abstinence and greater odds of both cessation failure and relapse, as in our previous RMLCA (McCarthy et al., 2015). Although these effects were not significant in the high-dose patch study, they were generally in the same direction. There was an unexpected association between higher FTND scores and lower risk of relapse among early quitters in the bupropion SR and counseling trial, but not in the other studies, including the 6-arm RCT (McCarthy et al., 2015). More past quit attempts were associated with reduced risk of *Cessation Failure* in the group-CBT and high-dose patch studies, as in the 6-arm RCT (McCarthy et al., 2015). In addition, more past quitting was associated with greater risk of Relapse, an effect not observed in the previous RMLCA (McCarthy et al., 2015). These data suggest that more experience quitting is helpful in initiating cessation, but that a history of multiple past relapses are associated with greater relapse risk in an index attempt, although the extent of this association may vary by sample, treatment, or situation.

4.4.4. Baseline craving. Baseline craving was associated with lower odds of sustained abstinence in only the bupropion SR and counseling RCT, although greater pre-quit craving was also associated with greater relapse risk relative to sustained intermittent smoking in the group CBT study. Craving was not significantly related to latent class in our earlier RMLCA (McCarthy et al., 2015), in which baseline self-efficacy and sleep were more robustly related to class. The items and scales used to assess craving differed across studies, which may contribute to the varying results. The lack of robustness in these relations across studies suggests they have limited potential to serve as markers of early smoking patterns.

4.5. Limitations

Both a limitation and a strength of the current study is the diversity of the studies included. The datasets were collected using different screening criteria, research designs, and assessment batteries by two investigative teams. As such, study is likely a potent source of variance reflecting the influence of many factors. Despite this, the latent class structure was replicated across studies, although many specific covariate relations with latent classes did not. The relatively small size of the samples in the individual studies may have limited power and contributed to inconsistencies in the pattern of covariate relations across studies. Also, results may not replicate among self-quitters, as all participants in the current studies were screened for high levels of motivation and volunteered for relatively demanding intervention studies. Complementary Markov modeling approaches that provide more specific information about particular transition probabilities (*i.e.*, relapse), such as that developed by Killeen (2011) will enhance our understanding of treatment and covariate effects on smoking cessation outcome.

4.6. Conclusions

Five common patterns of daily smoking at the outset of a smoking cessation attempt have been identified in four independent samples of adult smokers in smoking cessation studies. Tobacco dependence and smoking history are associated with these patterns, and smoking cessation therapies, particularly pharmacotherapies, influence smoking patterns in the early phases of quitting. Early patterns of smoking in the first weeks of a quit attempt presage later abstinence outcomes.

Contributors

D. E. McCarthy contributed to the conceptualization of the project, prepared data for analysis, and drafted the manuscript. L. Ebssa conducted data analyses, prepared tables and figures, and assisted in the writing of the manuscript. K. Witkiewitz contributed to the conceptualization of the project, provided expert guidance regarding data analysis, and assisted in writing the manuscript. S. Shiffman contributed to the conceptualization of the project, contributed two datasets for analysis, guided data analytic choices, and contributed to the writing of the manuscript. All authors have approved the final manuscript.

Conflict of interest

GlaxoSmithKline donated active and placebo medication for the randomized clinical trial of bupropion SR and counseling and the high-dose patch study re-analyzed in the present paper. Dr. McCarthy has received discounts on nicotine lozenge purchases from GlaxoSmithKline in the past. GlaxoSmithKline played no role in the design, implementation, analysis, or reporting of the studies. Dr. Shiffman has consulted to GlaxoSmithKline on smoking and smoking cessation, and currently consults with Niconovum on smoking cessation and Reynolds American Incorporated on tobacco harm minimization. No one from GlaxoSmithKline, Niconovum, or Reynolds American Incorporated were involved in any way in the conceptualization, implementation, analysis, or reporting for this project.

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