Nicotine & Tobacco Research, 2016, 1–9
doi:10.1093/ntr/ntw173
Original investigation

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Transitions in Smokers' Social Networks After Quit Attempts: A Latent Transition Analysis

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Abstract

Introduction: Smokers' social networks vary in size, composition, and amount of exposure to smoking. The extent to which smokers' social networks change after a quit attempt is unknown, as is the relation between quitting success and later network changes.

Methods: Unique types of social networks for 691 smokers enrolled in a smoking-cessation trial were identified based on network size, new network members, members' smoking habits, within network smoking, smoking buddies, and romantic partners' smoking. Latent transition analysis was used to identify the network classes and to predict transitions in class membership across 3 years from biochemically assessed smoking abstinence.

Results: Five network classes were identified: Immersed (large network, extensive smoking exposure including smoking buddies), Low Smoking Exposure (large network, minimal smoking exposure), Smoking Partner (small network, smoking exposure primarily from partner), Isolated (small network, minimal smoking exposure), and Distant Smoking Exposure (small network, considerable nonpartner smoking exposure). Abstinence at years 1 and 2 was associated with shifts in participants' social networks to less contact with smokers and larger networks in years 2 and 3.

Conclusions: In the years following a smoking-cessation attempt, smokers' social networks changed, and abstinence status predicted these changes. Networks defined by high levels of exposure to smokers were especially associated with continued smoking. Abstinence, however, predicted transitions to larger social networks comprising less smoking exposure. These results support treatments that aim to reduce exposure to smoking cues and smokers, including partners who smoke.

Implications: Prior research has shown that social network features predict the likelihood of subsequent smoking cessation. The current research illustrates how successful quitting predicts social network change over 3 years following a quit attempt. Specifically, abstinence predicts transitions to networks that are larger and afford less exposure to smokers. This suggests that quitting smoking may expand a person's social milieu rather than narrow it. This effect, plus reduced exposure to smokers, may help sustain abstinence.

Introduction

Despite the well-known risks of smoking, approximately 18% of US adults smoke and 2100 youth become regular smokers everyday.[1] Each of these smokers exists within a social network of family, friends, coworkers, community members, and others. The size, amount of support, and composition of these networks, including the number of smokers in the social network, vary by person. Understanding how social networks and smoking influence one another over time may illuminate important influences on smoking initiation, cessation, and relapse risk.

Much of the research on social networks and smoking has focused on the relations between network features and smoking initiation or escalation among adolescents or younger smokers. Such research, for instance, shows that having a large number of daily smokers in one's social network is a risk factor for becoming a daily smoker[2] and for having a higher trajectory of future use (ie, smoking more cigarettes per day over time[3]). One mechanism underlying such patterns may be that adolescent smokers tend to sort into groups based on shared smoking behaviors.[4] For example, among adolescents, low smokers tend to befriend other low smokers, and smokers tend to drop low smokers from their social groups.[4,5] Thus, smoking may run in social networks because smokers seek each other out, rather than because smoking spreads within networks.[6] Other social network factors, such as social isolation, have also been linked to increased risk for smoking among adolescents.[7,8]

Research on the social networks of adult smokers has shown clearly that smoking within the social network, especially partner smoking, decreases smokers' odds of quitting successfully.[9–12] For instance, the Four Country Survey found that reductions in contact with smokers from wave 1 to wave 2 increased intent to quit, quit attempts, and successful cessation at wave 2.[13] Other social network factors, such as high social capital or support from close members of the network, have been linked to lower smoking rates and greater cessation success.[14–20] Some research suggests mechanisms by which social networks may affect cessation among adults. Observational data from the Framingham Heart Study suggests that smoking within a network influences network members' smoking through multiple mechanisms, including social norms, increased opportunity, and secondhand smoke exposure.[21] The authors asserted that social norms may be particularly influential and may be expressed via requests not to smoke, decreased availability of cigarettes, or smoking cessation within the network. Consistent with these ideas, successful quitters have attributed their motivation to quit to being pressured by others, wanting to set a good example, and feeling isolated as a smoker.[22,23] Of course, the concentration of smoking within social networks might be influenced by multiple mechanisms. Because most relevant data arise from observational, cross-sectional studies, it is difficult to draw firm conclusions about mechanisms.[24,25]

The current study expands on prior research by focusing on the nature of social networks among adult smokers and how cessation is related to changes in network composition. Although it is clear that smoking can influence adolescents' friendships,[5] and that network features can affect likelihood of cessation among adult smokers,[11] little is known about how successful cessation is related to subsequent network change among adults. Furthermore, previous studies have focused primarily on one type of social contact, such as friends, or have aggregated the total number of contacts into a composite score of social capital. In the current study, we focus on multiple types of social contacts, including friends, smoking buddies, and romantic partners, which allows us to identify various profiles of social networks and which types of social contacts are most and least likely to change over time. Although we have made great progress in understanding how quitting smoking affects physical and mental health,[26,27] we have made much less progress in understanding how it affects social context.

The goal of the current study is to use data from a longitudinal smoking cessation clinical trial to characterize social networks among smokers and to examine whether smoking status after a quit attempt predicts long-term change (ie, from year-to-year across a 3-year period) in multiple dimensions of smokers' social environments, including contact with smokers. This issue is potentially important because some network changes might support abstinence (eg, loss of smokers from the network, reduced contact with smokers, increased contact with nonsmokers), whereas other changes might undermine abstinence[28–30] (eg, reduced network size, reduced social closeness from loss of smoking friends). Such information may yield insights into the processes that sustain or counter abstinence and could inform interventions.[31,32]

Methods

Participants

A total of 1504 smokers (58% female, 83% Caucasian) initially enrolled in a long-term smoking-cessation trial conducted in Madison and Milwaukee, WI.[33] All participants smoked at least 10 cigarettes/day on average for at least the past 6 months, had an alveolar carbon monoxide (CO) level greater than 9 parts per million (ppm), and were motivated to quit smoking. Participants were excluded for using any form of tobacco other than cigarettes, currently taking bupropion, having a current psychosis or schizophrenia diagnosis, or for having medical contraindications for any of the study medications. All participants provided written informed consent, and the study was approved by the University of Wisconsin Health Sciences Institutional Review Board.

Study Sample

For the current analysis, participants (n = 691; 58% female) were included if they completed the assessment at baseline and at 1, 2, or 3 years post-target quit date (TQD) and provided data for predictors of interest (eg, demographic characteristics). Participants identified as Caucasian (83%), African American (14%), or another racial group (3%). At baseline, participants reported smoking an average of 21 cigarettes/day (SD = 8.9). The reduced sample was not different from the full sample on gender, race, or average number of cigarettes smoked at baseline. The reduced sample was slightly older (mean = 45.79, SD = 10.64) than the full sample (mean = 43.68, SD = 11.36; t[1502] = 3.70, p < .05).

Procedures

Interested smokers completed a telephone screen. Potentially eligible smokers attended an information session where they learned about the study and provided written informed consent. Next, participants completed three in-person baseline sessions in which they underwent further screening and completed demographic, smoking history, and tobacco dependence assessments. Participants also completed a social network assessment interview in which they identified the most important members (up to nine) of their social networks and whether they had romantic partners. As part of this extensive interview, participants reported the following for each member of their network: gender, age, relationship (eg, family, friend), in what

setting s/he saw this person (eg, socially, work/school), how often s/he socialized with this person, the amount of emotional support this person provided, the amount of stress this person created, and this person's smoking patterns, including whether s/he and this person smoked with one another. We also asked participants to report whether network members were considered "smoking buddies," defined as people with whom they spent time on a regular basis to engage in activities that centered around smoking. The social network assessments were repeated at each annual assessment (1, 2, 3 years post-TQD); participants were asked to update their network members and assessments of them.

Eligible participants were randomized in a double-blind manner to one of six treatment conditions: (1) bupropion, (2) nicotine lozenge, (3) nicotine patch, (4) nicotine patch + nicotine lozenge, (5) bupropion + nicotine lozenge, or (6) placebo. In addition to pharmacotherapy, all participants received six one-on-one counseling sessions based upon the Public Health Service Clinical Practice Guideline.[34] Smoking status (CO < 10 ppm = abstinent) was assessed at study visits on their TQD (ie, baseline), at 1, 2, 4, and 8 weeks post-TQD, and at 1, 2, and 3 years post-TQD.

Smokers' Social Network Indicators

From the social network assessment interview, nine indicators were used to identify and describe smokers' types of social networks using smoking-specific network characteristics (eg, smoking buddies, time spent with smokers), as well as general network characteristics (eg, network size, new members). We focused on these indicators because of our interest in understanding how smokers' networks changed with respect to smoking-related characteristics following a smoking cessation attempt.

The selected indicators were coded as binary variables based on self-report responses regarding members of participants' networks (see Table 1). Cutpoints were determined based on empirical distributions across the response options (in order to achieve meaningful numbers of participants at each level) and on theoretical considerations. The nine indicators included the following.

(1) *Network size* indicated whether participants identified nine members (the total possible, excluding romantic partners) in their networks (yes/no). On average, adults have about 300 meaningful ties with others and in-depth interviews, like the one used in this study, facilitate reporting.[35] However, recall biases appear after asking individuals to recall more than about nine bits of information.[36] This indicator served as a proxy for comparatively large versus comparatively small social networks (ie, it served as an indicator of social isolation). (2) *New members* indicated whether participants reported that there were two or more new members in their networks since the last assessment (yes/no). (3) *Daily smokers* indicated whether participants identified two or more network members as daily smokers (yes/no). (4) *Never-smokers* indicated whether participants identified two or more network members as never-smokers (yes/no). (5) *Smoking exposure via network* indicated whether participants reported that two or more network members smoked a medium amount or a lot when the participant was with them (yes/no). (6) *Smoking with network members* indicated whether participants reported that they had two or more network members with whom they smoked a medium amount or a lot when they were with the members (yes/no). (7) *Smoking buddy group* indicated whether participants reported that they had smoking buddies (in-network or not). (8) *Smoking buddies in network* indicated whether participants reported that at least one of the individuals they identified as part of their networks was a smoking buddy (yes/no). (9) *Romantic partner who smokes daily* indicated participants who reported that they were living with a romantic partner (eg, spouse, domestic partner) who smoked daily (no = the participant either did not have a partner or the partner did not smoke).

Predictors of Social Network Classes

Demographic characteristics, network size at baseline, cigarettes smoked per day at baseline, and treatment status were considered as predictors of social network classes at 1 year post-TQD and abstinence was considered as a predictor of transitions at 2 and 3 years post-TQD. Demographic characteristics included gender

Table 1. Frequency Distributions for the Latent Transition Analysis Indicators of Smokers' Social Networks

Indicator	Label	1 year post-TQD		2 years post-TQD		3 years post-TQD	
		n	%	*n*	%	*n*	%
Network size	Less than 9	397	57	364	53	372	54
	All 9	294	43	327	47	319	46
New members	None or 1	189	27	196	28	210	30
	2 or more	502	73	495	72	481	70
Daily smokers	None or 1	335	48	320	46	349	51
	2 or more	356	52	371	54	342	49
Never-smokers	None or 1	129	19	126	18	125	18
	2 or more	562	81	565	82	566	82
Smoking exposure via network	None or 1	438	63	442	64	462	67
	2 or more	253	37	249	36	229	33
Smoking with network members	None or 1	475	69	462	67	493	71
	2 or more	216	31	229	33	198	29
Smoking buddy group	No	585	85	587	85	590	85
	Yes	106	15	104	15	101	15
Smoking buddies in network	None	641	93	642	93	647	94
	1 or more	50	7	49	7	44	6
Partner who smokes daily	No	556	80	561	81	559	81
	Yes	135	20	130	19	132	19

n = 691. TQD = target quit date.

(male/female), race (Caucasian/non-Caucasian), and age (continuous). Baseline network size assessed how many network members participants named pre-TQD (0–9); baseline cigarettes assessed how many cigarettes participants smoked per day on average pre-TQD (continuous). Abstinence (yes/no) at 1, 2, and 3 years post-TQD was biochemically assessed (CO < 10 ppm = abstinent). Intervention group membership was coded as placebo or active pharmacotherapy.

Analysis Plan

Statistical analyses proceeded in four steps. First, frequency tables were used as descriptive statistics to examine the distributions of the smokers' social network indicators at 1, 2, and 3 years post-TQD. Second, we used latent class analysis (LCA) and latent transition analysis (LTA)[37,38] to identify and describe the number of subgroups of individuals across 1, 2, and 3 years post-TQD based on the smoking-specific and general characteristics of their social networks (ie, social network indicators).

Using LCA, models with two to nine classes were preliminarily considered at each wave to provide guidance during model selection with LTA. Using LTA, models with two to nine classes were considered to determine whether subgroups of participants with unique types of social networks could be identified across 1, 2, and 3 years post-TQD. Model selection was based on the Akaike information criterion (AIC[39]) and Bayesian information criterion (BIC[40]), as well as model stability and interpretability.

Three sets of parameters were of interest: item-response probabilities that represent the probabilities of providing particular responses to particular items conditional on latent class membership, and that provide the foundation for interpreting the latent classes; latent class membership probabilities that represent the sizes of the latent classes at each wave; and transition probabilities that represent the probabilities of transitioning to classes at wave $t + 1$ conditional on membership in a particular latent class at wave t. PROC LCA and PROC LTA[41] were used to estimate these models; maximum likelihood estimate identification was confirmed for all models using 200 sets of random starting values.

Third, we used our selected LTA to examine change over time in social network class membership from 1 to 2 years post-TQD and 2 to 3 years post-TQD. Fourth, we added covariates to our selected LTA to test whether demographic characteristics, baseline social network size, baseline cigarettes per day, and treatment status predicted class membership at 1 year post-TQD and whether smoking abstinence predicted transitions between classes from 1 to 2 years post-TQD and 2 to 3 years post-TQD. Continuous predictors (ie, age, network size, cigarettes per day) were standardized as suggested by Lanza, Collins, Lemmon, and Schafer.[42]

Results

Descriptive Statistics

Descriptive statistics for the indicators used to identify smokers' social network classes appear in Table 1. There was a high degree of similarity in response distributions across years post-TQD. For example, 81%–82% of participants reported that at least two members of their social networks were never-smokers at 1, 2, and 3 years post-TQD. However, there were changes in participants' network members during that time—70%–73% of participants reported that at least two members were new to their networks since the last assessment. Interestingly, some of the indicators were endorsed relatively infrequently; for example, across all assessments, less than 10% of participants reported that they had a smoking buddy in their networks and only about 20% had a romantic partner who smoked daily.

Identification and Description of Social Network Types

Individual LCAs for 1, 2, and 3 years post-TQD suggested that five classes optimally explained the heterogeneity in smokers' social network characteristics (results available upon request). Using these preliminary results as a guide, LTAs across 1–3 years post-TQD with two to nine latent classes were compared to confirm selection of the five-class model; final model selection was conducted with LTA due to increased power to detect latent classes. Model selection information is presented in Table 2. Minimum AIC and BIC values indicate an optimal balance of model fit and parsimony.[37] The BIC was minimized for the five-class model and, although there was not a clear minimum value, the AIC suggested a low level of information loss by selecting the five-class model over the six-class model.

Parameter estimates for the five-class model appear in Table 3 (note that item-response probabilities were restricted to be equal across 1–3 years post-TQD to keep the interpretation of the latent classes the same over time). The first class, labeled *Immersed* (9%–11% prevalence), was characterized by members' social networks being likely to be large in size (item-response probability = .63), to have new members (.81), and to include both daily (.90) and never-smokers (.79), with participants likely to smoke around network members (.77) and vice versa (.78). Further, Immersed participants were the only ones who were likely to have a smoking buddy group (1.00), with those buddies likely to be present in their networks (.62). Notably, their partners tended not to be daily smokers (.27). Class 2, labeled *Low Smoking Exposure* (23%–26% prevalence), also had large networks with new members, but was distinguished from the Immersed class by a lack of the following: daily smokers in their networks, exposure to smoking, smoking with network members, a smoker buddy group, or a partner who smoked daily. Across all of the classes identified, Immersed and Low Smoking Exposure illustrate the extremes in smokers' social environments.

The other three identified classes, labeled *Smoking Partner* (9%–11% prevalence), *Isolated* (22%–27%), and *Distant Smoking Exposure* (29%–32%), were characterized by particular aspects of smoking exposure and/or network size. The Smoking Partner class was characterized by limited exposure to smoking and smaller social networks. They were unique in their high likelihood of having

Table 2. Model Fit and Selection Criteria for Latent Transition Analyses Across 1–3 Years Post-Target Quit Date

No. of classes	AIC	BIC	G^2
2	9560.93	9665.30	9514.93
3	9164.27	9350.33	9082.27
4	8674.76	8960.66	8548.76
5	**8185.60**	**8589.50**	**8007.60**
6	8141.05	8681.08	7903.05
7	8014.82	8709.16	7708.82
8	7830.49	8797.28	7448.49
9	7808.46	8865.84	7342.46

Degrees of freedom for all models were more than 100 million; exact number available upon request. AIC = Akaike information criterion; BIC = Bayesian information criterion; G^2 = likelihood ratio fit statistic. Bold font indicates selected model.

Table 3. Parameter Estimates for the Five-Class Latent Transition Analysis for 1–3 Years Post-Target Quit Date

		Immersed	Low smoking exposure	Smoking partner	Isolated	Distant smoking exposure
		Class membership probabilities				
1 year post-TQD		.11	.23	.10	.27	.29
2 years post-TQD		.10	.26	.09	.22	.32
3 years post-TQD		.09	.25	.11	.26	.29
		Item-response probabilities				
Network size (all 9)		**.63**	**.85**	.32	.00	.49
New members (>1)		**.81**	**.89**	**.63**	.45	**.78**
Daily smokers (>1)		**.90**	.29	.28	.12	**.98**
Never-smokers (>1)		**.79**	**.98**	**.79**	**.74**	**.76**
Smoking exposure via network (>1)		**.78**	.07	.06	.02	**.82**
Smoking with network members (>1)		**.77**	.13	.16	.14	.50
Smoking buddy group (yes)		**1.00**	.07	.18	.06	.00
Smoking buddies in network (1 or more)		**.62**	.01	.05	.00	.00
Partner who smokes daily (yes)		.27	.02	**.97**	.00	.21
		Transition probabilities				
		2 years post-TQD				
1 year post-TQD	Immersed	.44	.09		.07	.37
	Low smoking exposure	.01	.80	.01	.10	.08
	Smoking partner	.09	.00	.77	.05	.09
	Isolated	.02	.17	.02	.61	.18
	Distant smoking exposure	.13	.08	.02	.08	.69
		3 years post-TQD				
2 years post-TQD	Immersed	.48	.03	.09	.07	.33
	Low smoking exposure	.02	.79	.00	.14	.06
	Smoking partner	.02	.00	.82	.04	.12
	Isolated	.00	.09	.02	.78	.11
	Distant smoking exposure	.09	.08	.05	.12	.65

Bold font indicates item-response probabilities above .50. Transition probabilities are interpreted as the probabilities of membership in classes at time $t + 1$ (columns) conditional on membership in classes at time t (rows); transition probabilities sum to 1.0 (within rounding error) within a row. TQD = target quit date.

romantic partners who were daily smokers. The Isolated class was characterized by smaller social networks without exposure to smoking from any source, and members of this class were least likely to report new network members. The Distant Smoking Exposure class was characterized by the types of members (new members, daily and never-smokers) reported by the Immersed class, but members of the Distant Smoking Exposure class reported a relative lack of close or intimate smoking exposure via smoking buddies or romantic partners.

In summary, the Immersed class represents smokers with extensive exposure to smoking via all routes except via the romantic partner; the Low Smoking Exposure class represents smokers with relatively large networks that comprise few smokers and little smoking exposure; the Smoking Partner class represents smokers who are exposed to smoking via a romantic partner but who have little other network exposure to smoking; the Isolated class represents smokers who have relatively small and unchanging networks and little network exposure to smoking; and the Distant Smoking Exposure class represents smokers who have smokers in their network but not smoking buddies or a romantic partner who smokes.

Transitions Between Social Network Classes

Transition probabilities representing transitions between classes 1–2 and 2–3 years post-TQD appear in Table 3. These probabilities are interpreted as the likelihood of membership in a network class at wave $t + 1$ (columns) conditional on membership in a network class at wave t (rows). Shaded values represent the "stability" parameters—the probabilities of membership in the same class at adjacent timepoints, whereas other values represent the probabilities of changing memberships. For example, 44% of Immersed participants at 1 year post-TQD were members of the Immersed class at 2 years post-TQD, whereas 9% of them had transitioned to Low Smoking Exposure, 2% to Smoking Partner, 7% to Isolated, and 37% to Distant Smoking Exposure. From 1 to 2 years post-TQD, Immersed participants were most likely to transition to a different social network class (a total of 56%) and Low Smoking Exposure participants were least likely to transition (20%). For participants who were members of the two classes with the most movement, Immersed and Isolated, those who transitioned were most likely to transition to Distant Smoking Exposure. Transitions for 2–3 years post-TQD showed a similar pattern.

Predicting Initial Class Membership and Transitions

Effects on Year 1 Class Membership

Estimates for the effects of demographic characteristics, baseline social network size and cigarettes per day, and treatment status on social network class membership at 1 year post-TQD are shown in

Table 4. Effects are reported as odds ratios expressing the change in odds of membership in all other classes compared to a reference class, for a one-unit increase in the predictor. Low Smoking Exposure was used as the reference class because it was thought to represent a class at comparatively low risk for smoking relapse. In comparison to Low Smoking Exposure, members of the other classes differed in their mean ages and baseline network size (*p*s < .05). In comparison to Low Smoking Exposure, members of the Immersed, Smoking Partner, Isolated, and Distant Smoking Exposure classes were younger and had smaller networks at baseline. For example, the odds of membership in the Immersed class compared to membership in the Low Smoking Exposure class decreased by a factor of .55 for every one SD increase in age (mean age of sample = 45.79 [SD = 10.64], providing a sense of scale for these differences). Class membership at 1 year post-TQD did not differ significantly by gender, race, baseline cigarettes per day, or treatment status (see Table 4).

Effects on Transitions for Years 1–2 and 2–3 Post-TQD

Estimates for the prospective effects of biochemically assessed smoking abstinence on transitions between classes 1–2 and 2–3 years post-TQD are shown in Table 5; effect estimates were made in reference to staying in the same class between assessments. As noted earlier, compared to members of other classes, participants in the Immersed class were more likely to transition to other social network classes over time; due to larger transition probabilities, effects were more reliably estimated for these transitions. Abstinence was strongly related to transitions from the Immersed class. For example, among participants who were members of the Immersed class at 1 year post-TQD, those who were abstinent were 8.63 times more likely to transition to Distant Smoking Exposure rather than staying Immersed, compared to those who were not abstinent at 1 year post-TQD. In comparison, abstinence was associated with lower odds of all other transitions 1–2 years post-TQD for Immersed participants. The pattern of odds ratios for 2–3 years post-TQD had one difference: abstinence was associated with higher odds of transitioning to either Low Smoking Exposure or Distant Smoking Exposure among individuals who were Immersed at 2 years post-TQD.

As noted earlier, the most common transition endpoint was Distant Smoking Exposure; transitions into this class were highly related to

Table 4. Effects of Predictors on 1 Year Post-Target Quit Date Latent Class Membership

	Immersed		Low smoking exposure		Smoking partner		Isolated		Distant smoking exposure	
	OR	*B*	OR	*B*	OR	*B*	OR	*B*	OR	*B*
Gender (ref = male)	2.26	.82	–	–	1.55	.44	1.03	.03	1.53	.43
Age[a]	0.55	–.60	–	–	0.88	–.12	0.80	–.23	0.53	–.63
Race (ref = Caucasian)	1.62	.48	–	–	2.38	.87	2.87	1.05	1.92	.65
Baseline network size[a]	0.40	–.93	–	–	0.30	–1.20	0.20	–1.62	0.45	–.80
Baseline cigarettes per day	1.16	.15	–	–	1.12	.12	1.24	.22	1.40	.34
Treatment status	0.57	–.57	–	–	1.28	.24	0.92	–.08	1.19	.17

Dashes indicate reference latent class for the baseline category multinomial logistic regression model. OR = odds ratio.
[a]Overall effect of predictor is significant at $\alpha < .05$.

Table 5. Effects of Smoking Abstinence on Transitions Between Latent Classes for 1–2 and 2–3 Years Post-Target Quit Date

	Top entry: ORs for 1–2 years post-TQD Bottom entry: ORs for 2–3 years post-TQD Membership at *t* + 1 years				
Membership at *t* years	Immersed	Low smoking exposure	Smoking partner	Isolated	Distant smoking exposure
Immersed	–	0.43	[b]	0.47	8.63
	–	9.65	0.37	0.51	1.37
Low smoking exposure	[b]	–	[b]	0.47	0.75
	[b]	–	[b]	0.73	0.60
Smoking partner	[a]	[a]	–	[a]	[a]
	[b]	[b]	–	1.01	0.04
Isolated	[b]	1.07	[b]	–	0.33
	[b]	6.83	[b]	–	0.29
Distant smoking exposure	0.19	34.35[c]	[b]	0.40	–
	0.35	1.77	0.03	1.27	–

Dashes indicate reference latent class for the baseline category multinomial logistic regression model. Year 1–2 transitions were predicted by biochemically assessed abstinence at 1 year post-TQD and year 2–3 transitions by biochemically assessed abstinence at 2 years post-TQD. OR = odds ratio; TQD = target quit date.
[a]Indicates cell whose estimation was skipped due to small sample sizes in the latent contingency table among abstinence, Smoking Partner latent class membership at 1 year post-TQD, and latent class memberships at 2 years post-TQD, which prevented estimation of the multinomial logistic regression model.
[b]Indicates estimate based on transition probability of 2% or less that has been suppressed due to limited interpretability.
[c]The large size of this odds ratio is likely due to small sample sizes in the latent contingency table among abstinence, Distant Smoking Exposure latent class membership at 1 year post-TQD, and Low Smoking Exposure latent class membership at 2 years post-TQD.

smoking and smoking abstinence. For example, among members of the Isolated class at 1 year post-TQD, the odds of membership in the Distant Smoking Exposure class 2 years post-TQD compared to membership in the Isolated class decreased by a factor of .33 for those who were abstinent compared to those who smoked. Abstinence was also strongly related to transitions into the Low Smoking Exposure class. For example, abstinent members of the Distant Smoking Exposure class at 1 year post-TQD were 34.35 times more likely to transition to the Low Smoking Exposure class versus not transitioning at 2 years post-TQD, compared to smoking members of that class. (Note that the large size of this odds ratio is likely due to small sample sizes in the latent contingency table among abstinence, Distant Smoking Exposure latent class membership, and Low Smoking Exposure latent class membership.) Also, abstinent members of the Isolated class at 2 years post-TQD were 6.83 times more likely to transition to Low Smoking Exposure versus not transitioning at 3 years post-TQD, compared to smoking members of that class.

Discussion

The current research identified social network classes based on smoking-relevant characteristics and described how membership in these classes changed over time depending on whether smokers became abstinent or continued smoking. This research identified five latent classes of social networks that could be distinguished on the dimensions of size and amount of contact with smokers within the network. Participants were fairly evenly distributed across the latent classes (ie, networks types). Interestingly, the most prevalent network classes across all assessments (Low Smoking Exposure, Isolated, Distant Smoking Exposure) were those with relatively little intimate contact with smokers (ie, no smoking buddies or smoking partners), whereas the two least prevalent classes (Immersed, Smoking Partner) were the ones characterized by this intimate exposure. This finding may suggest that smokers in intimate relationships with other smokers may be less likely to attempt to quit and, therefore, less likely to be present in this sample.[12,14] Further, in three of the classes (Low Smoking Exposure, Smoking Partner, Isolated) participants reported at most one daily smoker in their social networks. Such modest representation of smokers in the classes may reflect the decreasing smoking prevalence in the United States.[43] Alternatively, it could represent attempts by smokers seeking cessation treatment to limit their exposure to smoking.

As seen in previous research,[13,21,44] smokers with limited exposure to other smokers (ie, those in the Low Smoking Exposure class) had the highest abstinence rates over time (53%–59%). Further, participants in this class were significantly older than those in other classes. It may be that Low Smoking Exposure class membership is related to a relatively developed network with more mature members who are less likely to smoke. Both age and reduced exposure to other smokers are associated with cessation success and reduced relapse risk.[45,46]

The Immersed (7%–9%) and Smoking Partner (25%–29%) classes had the lowest abstinence rates over time. This illustrates that either multiple sources of smoking exposure, in the former, or a single, intimate exposure source, in the latter, may discourage abstinence. The elevated risk of continued smoking among members of the Smoking Partner class is consistent with other research showing that having a partner who smokes can undercut cessation success.[10,14,47] Such findings underscore the importance of interventions that address partner smoking. Of course, having networks that involve high levels of smoking exposure may be correlated with other factors (eg, alcohol use, lower educational status) that may instead account for observed relations between class membership and smoking outcomes.

After establishing the social network classes, LTA was used to examine how classes changed as a result of smoking status. Abstinence predicted transitions from the Isolated to the Low Smoking Exposure and Distant Exposure Smoking classes, representing a shift to larger social networks. Although the Low Smoking Exposure and Distant Exposure Smoking classes had bigger networks, addressing potential social isolation, they also had at least one daily smoker whereas Isolated networks did not. This shift conflicts with studies of adolescents' friendship selection, in which low smokers tended to befriend other low smokers.[5]

Another key set of transitions involved the Immersed class, which was characterized by the highest levels of smoking exposure from multiple sources and by especially heavy smoking. This was the most dynamic class; over half of its members transitioned out between assessments. At both 1 and 2 years post-TQD, abstinence predicted movement out of the Immersed class over the subsequent year. Immersed class participants most commonly transitioned to the Distant Smoking Exposure class, characterized by a lower likelihood of "smoking buddies," or to the Low Smoking Exposure class, characterized by a relative absence of daily smokers. This pattern could result from smokers (1) transitioning out of the Immersed class in preparation for quitting, (2) who quit successfully no longer smoking with network members, and/or (3) who quit successfully no longer maintaining social ties with smoking friends. Alternatively, it could reflect previous smoking friends dropping them from their networks.[5] Finally, abstinent members of the Distant Smoking Exposure class at 1 year post-TQD were more likely than smoking members to transition to the Low Smoking Exposure class at 2 years post-TQD, representing a change to a larger network with less exposure to daily smoking. Overall, our findings suggest that abstinence is associated with shifts in participants' social networks such that they shift to networks that are larger and that result in less contact with, and exposure to, smokers.

These findings may have important clinical implications. On the one hand, these findings may merely indicate that those who are successful at quitting smoking are more likely to transition to networks that entail less exposure to smoking. On the other hand, the results may also reflect the fact that exposure to smoking and smokers discourages abstinence. The latter mechanism is supported by considerable other research[9,10] and supports further development of behavioral interventions designed to reduce exposure to smokers and smoking cues during quit attempts and to help smokers with small networks engage in new social activities that would allow them to befriend nonsmokers.[34,48] In addition, counselors could use these results to reassure smokers that quitting tends to increase, not decrease, the size of social networks.

Limitations and Conclusion

There are several limitations to consider when interpreting the results of the current study. First, there were three factors that may limit generalizability: (1) the sample comprises those who were interested in making a quit attempt with a relatively intense cessation treatment and may not be representative of smokers in general; (2) data from fewer than half of the original participants were analyzed due to missing data on the predictors used in analyses; and (3) the social network data were based on self-report. Second, there was some overlap among the variables used as indicators,

predictors, and outcomes. For instance, latent classes were identified using an indicator of participants' reports of smoking with network members. Thus, successfully quitting smoking would affect membership in classes partially defined by smoking with network members. However, most of our indicators did not overlap to this extent. Third, only dichotomous indicators were used in the models. Models with mixed dichotomous and continuous indicators can be difficult to estimate and interpret. Therefore, we used only dichotomous variables to facilitate interpretation. Fourth, we focused on smoking exposure and did not use other potentially important variables to define social networks (eg, amount of social support for quitting, interpersonal stress). Future research is needed to examine a broader range of variables that may help characterize smokers' social networks over time. Fifth, LCA and LTA provide a way to understand the heterogeneity in smokers' social networks, but the nature of the classes may be affected by diverse factors (eg, the nature of the sample). Therefore, it is important not to reify these classes. Finally, the causal directions of the relations cannot be ascribed with certainty. For instance, smoking exposure in the Immersed class may thwart quitting, or it may be that those who do not quit successfully do not change their networks. Future research is needed to disentangle these relations.

In conclusion, this study provides new insight into the relations between smoking and social networks. Prior research has shown that features of adult smokers' social milieu may affect the likelihood of future smoking cessation.[9,10] The current study identifies the features of social networks that occur among adult smokers, and how quitting smoking is related to change in such networks. Specifically, social networks defined by the highest levels of smoking and exposure to smokers were also most highly associated with continued smoking. Moreover, when smokers quit smoking they tended to enter networks that were larger, contained fewer smokers, and that involved fewer close relations with smokers.

Funding

This research was conducted at the University of Wisconsin-Madison and The Pennsylvania State University and was supported by awards P50-DA019706, P50-DA039838, and P50-DA010075 from the National Institute on Drug Abuse (NIDA), K05-CA139871 from the National Cancer Institute (NCI), and M01-RR03186 from the General Clinical Research Centers Program of the National Center for Research Resources (NCRR). The content is solely the responsibility of the authors and does not necessarily represent the official views of NIDA, NCI, NCRR, or the National Institutes of Health.

Declaration of Interests

None of the authors have any financial interests or connections, direct or indirect, or other situations that might raise the question of bias in the work reported or the conclusions, implications or opinions stated—including pertinent commercial or other sources of funding for the individual authors or for their associated departments and organizations, personal relationships, or direct academic competition.

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