



Original investigation

WISDM Primary and Secondary Dependence Motives: Associations With Smoking Rate, Craving, and Cigarette Effects in the Natural Environment

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Abstract

Introduction: The Wisconsin Inventory of Smoking Dependence Motives (WISDM) is a multidimensional measure of smoking motives that was developed to facilitate research aiming to refine the nomological network surrounding tobacco dependence. Recent evidence suggests that a composite of four subscales, termed the Primary Dependence Motives (PDM), may represent core features of advanced addiction, while the remaining nine subscales (Secondary Dependence Motives; SDM) represent instrumental motives for cigarette use that may be relevant at any stage of smoking.

Methods: A sample of 255 smokers (all regular alcohol users) participated in an ecological momentary assessment study in which they monitored smoking behavior and related experiences for 21 days. Multilevel regression analyses tested how PDM and SDM predicted daily smoking rate, cigarette craving, and appraisals of pleasure and relief of unpleasant feelings from smoking.

Results: When PDM and SDM were entered simultaneously, only PDM was related to daily cigarette count, and only SDM predicted reports of craving and relief from unpleasant feelings from smoking. SDM was associated with reports of greater pleasure from smoking and PDM was associated with lower pleasure ratings. The Fagerström Test for Nicotine Dependence (FTND) was related to daily smoking rate and craving, but WISDM composites contributed incremental prediction.

Conclusions: The findings confirm that PDM indexes heavier use that is relatively unrelated to immediate consequences of smoking. SDM is not uniquely related to smoking heaviness, but is associated with craving and reports of pleasure and relief of unpleasant feelings derived from smoking during ad lib use.

Implications: This study extends the evidence for the distinction between the WISDM PDM and SDM. PDM scores are associated with heavier smoking and are relatively unrelated to immediate consequences of smoking. SDM is more strongly related to craving and reports of smoking-derived pleasure and relief of unpleasant feelings during ongoing use in daily life.

Introduction

The Wisconsin Inventory of Smoking Dependence Motives (WISDM) comprises 13 subscales tapping distinct motivational processes hypothesized to influence smoking behavior according to varying theoretical perspectives.¹ The WISDM was developed to facilitate research aimed at refining the nomological network surrounding tobacco dependence.² Investigating the structure and correlates of diverse smoking motives has the potential to shed light on the ontology and central features of tobacco dependence.

Piper et al.³ used latent profile analyses to characterize common patterns of smoking motives in four samples of smokers. In each sample, they identified five profiles of WISDM subscale scores, with four of these groups showing comparable elevations across all subscales and differing only quantitatively with respect to profile elevation. However, the fifth group in each sample differed from the others configurally, showing more selective elevations on only four subscales: Tolerance, Automaticity, Craving, and Loss of Control. These were labeled the Primary Dependence Motives (PDM). Factor analyses revealed that these subscales formed a coherent dimension and could be meaningfully distinguished from a second, correlated factor formed by the remaining nine subscales, dubbed the Secondary Dependence Motives (SDM).

To evaluate these factors, Piper et al.³ computed PDM and SDM summary scores for each individual and entered them into a series of regression analyses predicting dependence-relevant criteria. Multivariate tests revealed that PDM was the superior predictor of numerous dependence-relevant measures, including cigarettes per day, breath carbon monoxide, age of smoking initiation, and relapse to smoking after a quit attempt.³ Such findings suggest that the central features of the advanced tobacco dependence construct may be defined by the content of the PDM subscales—heavy, automatic cigarette use, a perceived loss of volitional control over smoking behavior, and intense, frequent craving for cigarettes. By contrast, the remaining SDM motives seem to represent less discriminating instrumental or opportunistic reasons for smoking (eg, affective or cognitive enhancement, social influences).⁴

Subsequent investigations have bolstered this empirical distinction between PDM and SDM. Relative to SDM, the PDM has been more robustly related to indicators of heavy, addicted smoking, including smoking behavior in the laboratory,⁵ daily (vs. occasional) smoking status,^{6–8} attributions for smoking ad-lib cigarettes to habit and a desire to reduce craving,⁶ and variants in neuronal nicotinic acetylcholine receptor subunit genes known to be associated with heavy cigarette use and smoking-related disease.^{9,10}

The purpose of the current investigation is to extend this line of inquiry by examining how PDM and SDM scores are associated with smoking behaviors and related experiences during ad lib cigarette use in the natural environment. We use data from an ecological momentary assessment (EMA) study to assess links between WISDM components and four outcomes: daily smoking rate, ratings of the pleasure and relief of unpleasant feelings derived from recent cigarettes, and the intensity of momentary craving for cigarettes.

On the basis of prior findings, we expected PDM and SDM would be substantially correlated with one another, and that each would be associated with the selected EMA measures when considered individually.^{3–6} We anticipated that a more differentiated pattern of findings would emerge when both PDM and SDM were entered in prediction models simultaneously, thereby emphasizing the variance unique to each composite. Because the PDM has been hypothesized to reflect heavy, automatic smoking that is relatively divorced from

its immediate consequences,⁴ we anticipated that PDM would be the stronger predictor of daily smoking rate and that PDM would not be robustly associated with ratings of cigarette effects. SDM was expected to be the superior predictor of pleasure and relief of unpleasant feelings from recent cigarettes because this composite is hypothesized to better capture instrumental smoking motives and contains subscales assessing affective and cognitive enhancement. Predictions concerning associations between WISDM composites and craving were less certain, as both PDM and SDM have been found to be associated with craving measures in laboratory studies manipulating smoking motivation^{5,11} and after a cessation attempt.³

Although our primary focus was on the differential correlates of PDM versus SDM, we also conducted analyses involving the briefer Fagerström Test for Nicotine Dependence (FTND)¹² to determine whether the WISDM composites provide surplus information relative to this widely used instrument. Past research indicates that FTND is more strongly related to the PDM than to the SDM composite.^{3,5,9} Accordingly, we tentatively predicted that, like the PDM, the FTND would be associated with heavier smoking and possibly craving, but not ratings of cigarette effects. We expected that the more comprehensive WISDM composites would contribute incremental prediction when entered in models alongside the FTND.

Method

Participants

Participants were recruited in and around the Columbia, Missouri community using mass emails, posted flyers, and print advertisements. These individuals represent a subset of participants taking part in a larger study ($N = 404$) focused on alcohol and cigarette co-use.¹³ All participants were required to have reported drinking alcohol four or more times in the past month. By design, approximately two-thirds of the sample was comprised of current smokers, defined as follows: (1) self-report of smoking at least one cigarette per week, (2) not regularly using non-cigarette tobacco products, (3) having no plans to quit smoking within the next 30 days, and (4) not currently using any smoking cessation pharmacotherapy. Additional eligibility for inclusion in the study included (1) the ability to speak, read and write English, (2) being 18 years of age or older, (4) no interest in seeking treatment for alcohol use, history of unsuccessful attempts to abstain from alcohol, or alcohol-related convictions (excepting status offenses), and (4) not currently pregnant or trying to become pregnant if female. The current analyses are limited to data provided by the subsample of current smokers who completed either the WISDM or the FTND ($n = 255$). Table 1 describes the sample characteristics. The sample was predominately white and balanced with respect to gender. Smokers ranged in age from 18 to 70, but the bulk of the sample consisted of young adults (Mdn = 22 years, 73% between 18 and 25 years). Most reported they were daily smokers at baseline (71%), and they tended to reported high quantity and frequency of alcohol use, consistent with the recruitment criteria. The University of Missouri and Washington University School of Medicine's Institutional Review Boards approved the study protocol and all participants provided informed consent. Additional findings from this study have been reported elsewhere,^{13–20} but no prior reports have examined correlates of the WISDM composites.

Diary Device and Procedure

Participants reported to the laboratory for a baseline session during which they completed a battery of questionnaires. At a second visit,

Table 1. Participant Characteristics (*N* = 255)

Measure	<i>n</i>	%
Male	137	53.7
Race		
American Indian or Alaskan Native	2	0.8
Asian	13	5.1
Black	7	2.7
Native Hawaiian or Pacific Islander	1	0.4
White	214	83.9
Other	16	6.3
Hispanic ethnicity	8	3.1
Marital status		
Single, never married	194	76.1
Single, living together	23	9.0
Married	25	9.8
Separated	2	0.8
Divorced	9	3.5
Daily smoker	181	71.0
Alcohol use frequency ^a		
2–4 times per month	46	18.0
2–3 times per week	138	54.1
≥4 times per week	70	27.5
Number of drinks per drinking day ^a		
1 or 2	40	15.7
3 or 4	63	24.7
5 or 6	65	25.5
7 to 9	53	20.8
≥10	34	13.3
	<i>M</i>	<i>SD</i>
Age	24.92	8.35
Cigarettes per day	8.68	11.41
FTND	2.17	2.24
WISDM PDM	3.19	1.56
WISDM SDM	3.63	1.21
AUDIT	12.29	5.71

AUDIT = Alcohol Use Disorder Identification Test; FTND = Fagerström Test for Nicotine Dependence; PDM = Primary Dependence Motives; SDM = Secondary Dependence Motives. Subtotals do not always sum to total sample size due to missing data. Cigarettes per day is based on self-report at baseline. For nondaily smokers, this was determined by calculating the product of number of cigarettes per smoking day and the number of smoking days per week (ie, cigarettes per week), then dividing the result by 7.

^aBased on responses to AUDIT items that contribute to AUDIT total score.

participants were issued a palmtop computer (Palm m500, Palm Inc., Sunnyvale, CA) programed with diary software custom written for the project by invivodata, inc. (Pittsburgh, PA). Participants were asked to carry the diary for 21 days. Study staff led participants through a tutorial on the use of the diary and answered any questions. At the end of this visit, participants began active recording. During the course of the study, participants visited the lab on four occasions so that study staff could back up diary records, review progress and compliance with the participant, and answer questions about the device or study protocol. Participants were compensated \$150 for completing all study visits and returning the diary device; pro-rated compensation was provided for partial study completion.

Diary Assessments and Compliance

The current analyses focus on 45 406 diary records collected from five types of diary records. The palmtop computers were programed to audibly prompt participants to log a diary entry up to five times

per day (Random Prompts). The analyzed participants made diary entries in response to 17 099 of the 21 700 audible prompts (78.8% compliance), and averaged 3.2 completed Random Prompt assessments per day. The diary was programed to serve as an alarm clock, and participants were audibly prompted to complete a diary entry each day upon waking (Morning Reports). Morning Report entries were made on 4553 of 5373 person-days (84.7% compliance). Participants were instructed to initiate a diary recording whenever they finished smoking a cigarette (Cigarette Reports). In order to limit assessment burden for heavier smokers, a battery of self-report items was only administered following the first cigarette logged within each 6 hour block of time. In the remaining instances, the diary merely asked the participant to confirm a cigarette had been smoked and then powered off. In total, participants logged 16 380 Cigarette Reports, of which 6486 (39.5%) were followed by a full diary assessment, averaging 3.1 full reports per day. Participants were also instructed to initiate a diary recording when they finished the first drink of alcohol in a drinking episode (Drink Reports, *n* = 1404). Reports of alcohol use triggered a set of audible prompts to complete additional reports (Drinking Follow-Ups) at 30-, 90-, and 150-minutes later to oversample the post-drinking state. The set of follow-ups was extensible, such that reports that one or more new drinks was consumed caused another Drinking Follow-Up to be scheduled for 60 minutes after the final one in the current queue. Participants completed 5970 of 7076 prompted follow-up assessments (84.4% compliance). Diary records were typically completed fully if initiated. Across the variables analyzed here, less than 2% of fields were missing due to abandoned diary entries. These observations were handled by casewise deletion.

Measures

Tobacco Dependence

Current smokers completed the WISDM¹ and the FTND¹² at the baseline session. The FTND consists of six items indexing aspects of physical dependence, such as morning smoking, heaviness of smoking, and difficulty refraining from smoking ($\alpha = 0.71$). The WISDM asks participants to indicate level of agreement with 68 items tapping the presence of theoretically identified smoking motives. Responses to each item are made using a Likert scale ranging from 1 (not at all) to 7 (extremely). Scores for each of the 13 WISDM subscales were computed by taking the average item scores for items belonging to each scale (α s = 0.86–0.95). Next, a PDM composite score was calculated for each participant by averaging the Automaticity, Craving, Loss of Control, and Tolerance subscales ($\alpha = 0.96$ for 18 items, 0.92 for 4 scale scores) and an SDM composite score was calculated by taking the average of the remaining subscales ($\alpha = 0.97$ for 50 items, 0.91 for 9 scale scores).

Diary-Based Dependent Measures

For each person-day, a daily cigarette count was calculated by summing the number of cigarettes reported across all record types. Cigarette Reports (whether or not they were followed by a complete interview) were counted as one cigarette. Random Prompts, Morning Reports, and First Drink Records included a yes/no question asking whether the participant had smoked within a certain time frame before the diary report (Random Prompts and First Drinks: past 15 minutes; Morning Report: since waking). One cigarette was counted when the participant answered “yes.” Drinking Follow-up Records asked participants “Since the last recording how many cigarettes have you smoked?” and allowed the participant to report the exact number of cigarettes they had smoked up to six

cigarettes (0–6 or more). The number of cigarettes recorded was added to the day's sum. The analyzed participants reported smoking 27 904 cigarettes during the study. On average, participants smoked on 79% of study days (range = 0%–100%, 25th percentile = 65%, Mdn = 91%, 75th percentile = 100%). The within-person daily average smoking rate on days when smoking occurred was 6.4 cigarettes ($SD = 5.6$, range = 1–44; 25th percentile = 2.0, Mdn = 5.0, 75th percentile = 9.0).

In every record type, current cigarette craving was measured with a single item that was worded identically across all assessments. Participants were asked to rate on a five-point Likert scale from 1 (not at all) to 5 (extremely) how much they felt craving for a cigarette within the past 15 minutes.

Reports of smoking in Cigarette Records, Random Prompts, Morning Reports, First Drink Records, and Drinking Follow-up Records triggered administration of items asking the participant to rate cigarette effects. (Note these items were not administered when Cigarette Records were not followed by a complete interview). Separate items served as proxies for positively reinforcing or rewarding effects (“Was the last cigarette pleasurable?”) and negative reinforcement (“Did the last cigarette relieve unpleasant feelings or symptoms?”). Participants rated agreement with each statement using a scale from 1 (not at all) through 5 (extremely).

Person-Level Covariates

Participant sex was coded as a dummy variable (women = 0, men = 1). Age was divided into dichotomous categories (eg, under 21, 21–30, 31–40, and over 40) represented in analyses by three dummy coded variables. Participants indicated whether or not they were a daily smoker using a smoking history questionnaire administered at baseline (Table 1). This was included as a covariate because prior work suggests these groups differ with respect to scores on the WISDM composites and the FTND^{6–8} and may differ with respect to stimulus control over smoking.²¹ Given that the sample was recruited for frequent drinking, a measure of alcohol use and involvement was included to account for the influence of problematic alcohol use on the results. The Alcohol Use Disorders Identification Test (AUDIT)²² is a ten-item measure of involvement in hazardous drinking that was administered at baseline. A cut score of eight on the AUDIT is frequently used to identify harmful or hazardous alcohol use.²² The majority of participants ($n = 195$, 76.5%) exceeded that threshold, as did the mean for the sample as a whole (Table 1).

Momentary Covariates

Time stamps on each diary record were used to create six bins indexing time of day (12–4 AM, 4–8 AM, 8 AM–12 PM, 12–4 PM, 4–8 PM, and 8 PM–12 AM), represented by five dummy coded variables in the analyses. Dichotomous variables were created to indicate whether the participant had or had not recently smoked or used alcohol. Recent smoking was counted as having occurred if (1) the record was a Cigarette Report, (2) the record was a Morning Report, Random Prompt, or First Drink and the participant answered the question about recent smoking affirmatively, or (3) the record was a Drinking Follow-Up and the participant reported having smoked one or more cigarettes since the last diary entry. Alcohol use was counted if (1) the record was a First Drink or Drinking Follow-up record, or (2) the record was a Cigarette Report or Random Prompt and the participant answered “yes” to a question asking whether alcohol had been consumed since the last diary report.

Statistical Analyses

Diary data were analyzed using a generalized linear mixed model framework with random intercepts at the participant level to account for the nested data structure.²³ For each diary-based outcome, we conducted a series of five models. Each model in a series incorporated a common set of covariates, but differed with respect to the tobacco dependence indicators included. Models 1–3 included a single dependence indicator (PDM, SDM, or FTND, respectively). In Model 4, PDM and SDM were jointly entered; this accounts for the shared variance between the two composites and tends to reveal a more differentiated set of relations of primary and secondary motives with external variables.^{3,5,6,9} Finally, in Model 5, PDM, SDM, and FTND were entered simultaneously to evaluate whether the WISDM composites contribute incremental information relative to the briefer and more widely-used FTND.

A generalized linear mixed model with a Poisson distribution and log link function was utilized in the current study for the cigarette count analyses as this is the appropriate model for predicting count outcome variables.²³ In these models, diary data were aggregated at the day level, with the cigarette tally for each day as the dependent measure. Each model included the person-level covariates (sex, age, daily vs. nondaily smoker status, and AUDIT score) but momentary covariates were not incorporated because the data were aggregated at the daily level (ie, collapsed across the momentary reports within each day). Model coefficients were exponentiated to yield incidence rate ratios (IRRs) which indicate the relative increase (or decrease) in smoking rate associated with a one-point change in the predictor.

For the models predicting cigarette craving, linear multilevel regression was used. These models included all person-level (sex, age, daily vs. nondaily smoker status, and AUDIT) and momentary covariates (time of day, recent smoking, and recent alcohol use). Models predicting cigarette effect ratings also used linear multilevel regression. The form of these models was the same as for cigarette craving, with the exception that recent smoking was omitted from the covariate set (because the items assessing cigarette effects were only administered when smoking had been reported).

Results

Tobacco Dependence

As shown in Table 1, participants averaged a score of 2.17 on the FTND (range = 0–8), 3.19 on WSDM PDM (range = 1.00–6.85) and 3.6 on the SDM (range = 1.00–6.73). As expected, PDM and SDM were significantly correlated ($r = 0.76$, $p < .001$). FTND was significantly associated with both WISDM composites, but more robustly related to PDM ($r = 0.69$, $p < .001$) than to SDM ($r = 0.49$, $p < .001$). This difference in correlations was statistically significant, $z = 5.74$, $p < .001$.

Cigarette Count

Table 2 summarizes results from models predicting daily cigarette counts. Each dependence measure was significantly associated with heavier smoking when entered alone (IRRs = 1.20–1.29, $p < .001$). When PDM and SDM were entered jointly in Model 4, PDM remained significant (IRR = 1.30, $p < .001$) but SDM was not uniquely related to smoking rate (IRR = 0.98, $p = .67$). When all three dependence indicators were entered in Model 5, higher FTND scores were associated with heavier smoking (IRR = 1.13, $p < .001$), PDM added incremental predictive information (IRR = 1.18, $p < .001$) and SDM was not significant (IRR = 0.95, $p = .28$).

Table 2. Results of Models Predicting Daily Cigarette Count

Model	IRR	95% CI	<i>p</i>
Model 1			
PDM	1.29	1.21, 1.37	< .001
Model 2			
SDM	1.22	1.13, 1.33	< .001
Model 3			
FTND	1.20	1.15, 1.25	< .001
Model 4			
PDM	1.30	1.19, 1.42	< .001
SDM	0.98	0.88, 1.09	.672
Model 5			
FTND	1.13	1.08, 1.19	< .001
PDM	1.18	1.08, 1.29	< .001
SDM	0.95	0.86, 1.04	.281

AUDIT = Alcohol Use Disorder Identification Test; FTND = Fagerström Test for Nicotine Dependence; IRR = Incidence rate ratio; PDM = Primary Dependence Motives; SDM = Secondary Dependence Motives. Each model included sex, age, daily vs. non-daily smoking status, and AUDIT score as covariates.

Craving

Results from models predicting cigarette craving are presented in the top portion of Table 3. Models 1–3 revealed that higher scores on each dependence indicator were associated with elevated craving when tested singly ($bs = 0.08$ – 0.25 , $ps \leq .001$). When PDM and SDM were entered together in Model 4, only SDM was significantly related to craving. When FTND was included in Model 5, neither FTND ($b = 0.02$, $p = .45$) nor PDM ($b = 0.04$, $p = .44$) were significantly associated with craving reports, but SDM remained a significant predictor ($b = 0.19$, $p = .001$).

Ratings of Cigarette Effects

The middle portion of Table 3 summarizes findings from models predicting ratings of the pleasure from the last cigarette. When each measure was entered alone, only SDM was significantly associated with reports of pleasurable effects of smoking ($b = 0.22$, $p < .001$). In Model 4, higher scores on SDM remained significantly associated with reported pleasure from smoking ($b = 0.37$, $p < .001$) and the unique variance in PDM was negatively related to pleasure ($b = -0.19$, $p < .001$). In Model 5, FTND was not related to pleasure ($b = -0.01$, $p = .59$) but both the positive association with SDM ($b = 0.37$, $p < .001$) and the negative relation with PDM ($b = -0.19$, $p < .001$) remained significant.

Results from models predicting relief of unpleasant feelings from smoking are given in the bottom portion of Table 3. As was found for pleasure, SDM was the only dependence indicator associated with relief when entered alone ($b = 0.20$, $p < .001$). SDM remained associated with relief in Models 4 and 5; PDM and FTND were not significant predictors of relief of unpleasant feelings when entered simultaneously with SDM.

Discussion

The WISDM instrument was developed to enable research elaborating the nomological network surrounding tobacco dependence. Prior research has suggested that the WISDM PDM measures a set of core features—heavy, habitual or automatic smoking accompanied by cravings—that may be more characteristic of advanced tobacco dependence. In contrast, the SDM appears to index a set

Table 3. Results of Models Predicting Momentary Cigarette Craving and Ratings of Cigarette Effects

Dependent measure/Model	<i>b</i>	95% CI	<i>p</i>
Craving			
Model 1			
PDM	0.18	0.11, 0.25	< .001
Model 2			
SDM	0.25	0.17, 0.33	< .001
Model 3			
FTND	0.08	0.03, 0.13	.001
Model 4			
PDM	0.06	-0.04, 0.15	.224
SDM	0.20	0.09, 0.32	.001
Model 5			
FTND	0.02	-0.04, 0.08	.452
PDM	0.04	-0.07, 0.15	.437
SDM	0.19	0.08, 0.31	.001
Cigarette pleasurable			
Model 1			
PDM	0.02	-0.05, 0.09	.530
Model 2			
SDM	0.22	0.14, 0.30	< .001
Model 3			
FTND	0.001	-0.05, 0.05	.960
Model 4			
PDM	-0.19	-0.28, -0.10	< .001
SDM	0.37	0.27, 0.48	< .001
Model 5			
FTND	-0.01	-0.06, 0.04	.662
PDM	-0.19	-0.28, -0.09	< .001
SDM	0.37	0.26, 0.48	< .001
Cigarette relieved unpleasant feelings			
Model 1			
PDM	0.06	-0.03, 0.15	.184
Model 2			
SDM	0.20	0.09, 0.30	< .001
Model 3			
FTND	0.01	-0.05, 0.07	.763
Model 4			
PDM	-0.08	-0.20, 0.04	.186
SDM	0.26	0.11, 0.41	.001
Model 5			
FTND	-0.02	-0.09, 0.05	.585
PDM	-0.07	-0.20, 0.07	.346
SDM	0.26	0.11, 0.41	.001

AUDIT = Alcohol Use Disorder Identification Test; FTND = Fagerström Test for Nicotine Dependence; PDM = Primary Dependence Motives; SDM = Secondary Dependence Motives. Craving models covaried sex, age, daily vs. non-daily smoking status, AUDIT score, time of day, recent smoking, and recent alcohol. Remaining models included the same covariates, except for recent smoking.

of instrumental or opportunistic reasons for smoking that may be relevant at any stage of smoking. The current findings support and extend these conclusions using intensive longitudinal data collected via electronic diaries during ad lib smoking.

As predicted, higher PDM scores were associated with heavier daily smoking. SDM was positively associated with smoking rate as well. However, when both composites were entered simultaneously, only PDM remained a significant predictor, indicating that the effect for SDM was attributable to variance shared with PDM. A different pattern of findings emerged when predicting ratings of cigarette effects. Higher SDM scores were consistently associated with

reports of pleasure and relief of unpleasant feelings from the last cigarette. PDM was not associated with these cigarette effects when tested alone. When PDM and SDM were entered simultaneously, the unique variance in PDM was associated with lower ratings of smoking-derived pleasure. Taken together, this set of findings corroborates the suggestion that PDM is associated with a pattern of heavier, habitual or compulsive use whereas SDM is more clearly tied to the consequences of smoking and may be more characteristic of elective, instrumental cigarette use.⁴ Indeed, relative to PDM, SDM appears to be more strongly related to conditions that may provide setting events for smoking-related relief or affective enhancement, including anxiety and anxiety disorders,^{24,25} and hazardous alcohol use.²⁶

We found that both PDM and SDM were associated with elevated craving in daily life when tested alone, but only SDM was uniquely related to craving when the two composites were entered simultaneously. Self-reported cravings can arise from multiple mechanisms and vary with respect to their affective valence.²⁷⁻²⁹ Although the PDM contains the WISDM Craving subscale, comprising four items asking about the frequency and intensity of cigarette craving, components of the SDM tap content related to some of hypothesized craving instigators and motivational correlates (eg, Cue Exposure, Positive Reinforcement, Negative Reinforcement).

To the extent that the PDM score indexes compulsive, automatic use driven by habit learning mechanisms,⁴ this composite may be especially related to “abstinence avoidance” cravings occasioned by interruption of an automatized self-administration routine.²⁹ In contrast, SDM may be a better predictor of cravings driven by other mechanisms, such as cue exposures or mood fluctuations. According to this perspective, the current findings might indicate that the most cravings experienced during ad libitum smoking are precipitated by contextual and subjective cues. PDM might emerge as a more robust predictor of craving under conditions of extended tobacco deprivation. Indeed, Piper, et al.³ found that both PDM and SDM were simultaneously associated with EMA-assessed craving following a cessation attempt.

Another possibility is that including daily versus nondaily smoking status as a covariate resulted in overly conservative tests. Relative to nondaily smokers, daily users spend a higher proportion of their days in active craving states³⁰ and tend to be especially elevated on PDM subscales.^{6,7} In the craving models reported in Table 3, daily smoking was consistently associated with higher craving intensity ($bs = 0.26-0.43$, $ps < .05$; not tabled). When this covariate was omitted from Model 4, both PDM and SDM were simultaneously significant predictors of craving, though the effect for PDM was weaker than that for SDM (PDM $b = 0.10$, $p < .05$; SDM $b = 0.22$, $p < .001$). The differences between these models may indicate overlapping variance components are shared among PDM, smoking patterns, and craving.

The FTND was significantly correlated with both WISDM composites in the current study, replicating existing findings.^{3,5,9} As seen in prior studies, the FTND was more robustly related to the PDM score than to the SDM, a finding that may be largely attributable to variance shared with the WISDM Tolerance subscale.^{1,31} As anticipated, the FTND and PDM showed similar patterns of association with EMA-measured outcomes; when tested alone, each was related to smoking heaviness and craving, but not reported cigarette effects. In models including PDM and FTND simultaneously, neither was independently associated with craving but both measures were significant predictors of smoking heaviness. The FTND contains an item explicitly assessing the respondents' typical number of

cigarettes per day, so predictor-criterion overlap may help to explain why it performed so with respect to this particular outcome. The PDM contains the Tolerance scale, which assesses similar content as the FTND (eg, morning smoking, heavy smoking, difficulty refraining), but also includes information from other scales concerning automaticity, impaired control, and cravings. This surplus content may contribute unique information relevant to individual differences in smoking rate.

The findings should be interpreted in the context of study limitations. Owing to the goals of the larger project, participants were required to be frequent drinkers and the diary protocol intensively oversampled experiences during active drinking episodes. Additionally, the sample was primarily composed of young adults, many of whom were light or nondaily smokers. It is uncertain how well the findings would generalize to studies with different sample characteristics or diary protocols. In order to manage assessment burden, the EMA protocol used simple, face-valid items to tap craving intensity and smoking-contingent pleasure and relief of unpleasant feelings. Different findings might have emerged if multi-item scales had been used to assess these outcomes, potentially increasing reliability and coverage of each domain. The diary did not assess potential contextual moderators (eg, smoking cue exposure, intensity of tobacco withdrawal) that might be useful for parsing some of the heterogeneity in craving processes. Similarly, we examined only a handful of dependence-relevant criteria. Finally, it is possible that the diary assessments and our procedures for tallying cigarettes (eg, assuming smoking in a Random prompt or Cigarette Report represented a single cigarette) resulted in an undercount of total cigarette consumption. Prior analyses of these data indicated that diary-captured cigarettes amounted to approximately 63% of the total that would be projected based on a 30-day retrospective, calendar-based measure administered at baseline.¹³ Notably, though, several sources of error could contribute to this discrepancy, some of which would not be inconsistent with accurate diary recording (eg, error or bias in retrospective reports of smoking, behavioral reactivity to self-monitoring). Nonetheless, in future work, it may be beneficial to incorporate direct assessments of number of cigarettes consumed since last report and use end-of-day assessments that allow participants to record any smoking events they were not able to record in real time.³²

In summary, the current study adds to the accumulating body of evidence supporting the distinctions between primary and secondary motives. The findings confirm that the unique variance in PDM indexes heavier use that is relatively unrelated to immediate consequences of smoking. SDM is not uniquely related to smoking heaviness, but is more strongly related to pleasure and relief derived from smoking. Both composites contribute to prediction of craving experiences in daily life.

In future work, it would be valuable to incorporate ecological assessments of other behavioral phenomena (eg, lighting cigarettes without awareness or intention) that could be used to probe hypothesized distinctions between PDM and SDM. More broadly, there is a need for developmental and clinical research evaluating the validity and utility of distinguishing the two motive composites. Long-term prospective studies of fledgling smokers are needed to directly test whether, as conjectured, PDM tend to emerge later in the smoking career and are associated with a more refractory course compared to SDM. Clinical research is needed to test whether PDM or SDM scores moderate responses to particular treatments, potentially suggesting new approaches for treatment matching.

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Declaration of Interests

None declared.

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