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Refining the tobacco dependence phenotype using the Wisconsin Inventory of Smoking Dependence Motives (WISDM)

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Abstract

The construct of tobacco dependence is important from both scientific and public health perspectives, but it is poorly understood. The current research integrates person-centered analyses (e.g., latent profile analysis) and variable-centered analyses (e.g., exploratory factor analysis) to understand better the latent structure of dependence and to guide distillation of the phenotype. Using data from four samples of smokers (including treatment and non-treatment samples), latent profiles were derived using the Wisconsin Inventory of Smoking Dependence Motives (WISDM) subscale scores. Across all four samples, results revealed a unique latent profile that had relative elevations on four dependence motive subscales (Automaticity, Craving, Loss of Control, and Tolerance). Variable-centered analyses supported the uniqueness of these four subscales both as measures of a common factor distinct from that underlying the other nine subscales, and as the strongest predictors of relapse, withdrawal and other dependence criteria. Conversely, the remaining nine motives carried little unique predictive validity regarding dependence. Applications of a factor mixture model further support the presence of a unique class of smokers in relation to a common factor underlying the four subscales. The results illustrate how person-centered analyses may be useful as a supplement to variable-centered analyses for uncovering variables that are necessary and/or sufficient predictors of disorder criteria, as they may uncover small segments of a population in which the variables are uniquely distributed. The results also suggest that severe dependence is associated with a pattern of smoking that is heavy, pervasive, automatic and relatively unresponsive to instrumental contingencies.

Introduction

The present research is aimed at a refinement of the features of the nicotine dependence phenotype. Distillation of a phenotype is of critical importance in experimental psychopathology as it permits investigators to focus on the assessment of core aspects of disorders. Knowledge of these core aspects permits investigators to target more accurately critical phenotypic features in genetic mapping efforts (e.g., Althoff et al., 2006; Baker et al.,

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in press; Todd et al., 2003). Finally, distillation may provide insight into the nature and etiology of the disorder and this may provide guidance regarding treatment development.

Certainly some progress has been made in identifying items and measures that are sensitive to nicotine dependence. Items have been identified that predict important dependence criteria such as relapse vulnerability and biochemical measures of smoking heaviness (Piper et al., 2006; Haddock et al., 1999; Foulds et al., 2006; Transdisciplinary Tobacco Use Research Center (TTURC) Nicotine Dependence Phenotype Working Group, 2007). However, there is need for additional progress. For instance, it is not known which features of smokers represent core aspects of dependence. Current dependence measures are not uniformly valid predictors of the various dependence criteria (e.g., relapse, withdrawal; Piper et al., 2006), there is considerable variation in the results of factor analyses of commonly used nicotine dependence scales (e.g., Breteler et al., 2004; Haddock et al., 1999; Heatherton et al., 1991), and different measures of nicotine dependence often disagree with one another in terms of the assessment of dependence severity (Moolchan et al., 2002; also cf. Breslau & Johnson, 2000). Thus, current evidence suggests the existence of multiple dimensions of dependence but has not revealed core features.

In an effort to understand the nature of nicotine dependence, numerous investigators have conducted person-centered analyses, such as latent class analyses (LCA), to explore whether different types of nicotine dependence exist, and if so, the features that define such types. One LCA study used data from the National Household Surveys on Drug Abuse and focused on the development of DSM (Diagnostic and Statistical Manual; APA, 1994) tobacco dependence symptoms in the 1-2 years following smoking initiation (Storr, Zhou, Lian & Anthony, 2004). This study found three classes of dependent individuals, with individuals appearing to differ quantitatively; i.e., they were segregated into those with no, moderate, or severe dependence. These results suggest the presence of three classes that differ in severity rather than in kind. Other studies have used LCA to analyze DSM symptoms of dependence (Muthén, 2006; Xian et al., 2007) and the Fagerström Test of Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991). These studies yielded classes that appeared to reflect dependence severity per se (Storr, Reboussin & Anthony, 2005). In addition, one study showed that the LCA of a nicotine dependence criterion (i.e., withdrawal symptoms) also produced a solution indicative of a single severity dimension (Madden et al., 1997). However, even when LCA suggests the presence of a strong severity dimension, it is possible that classes may differ in some respects. For instance, Muthén & Asparouhov (2006) used hybrid factor mixture models to analyze population-based data from current smokers, current drinkers and individuals who both smoke and drink. Their results suggest that smoker classes could be distinguished on the basis of different factor correlates within each class.

It is important to note that these results pertaining to nicotine dependence reflect a general pattern of findings obtained with other externalizing disorders (e.g., conduct disorder, addictive disorders, and antisocial personality disorder). Results of a large body of research (cf. Bucholz et al., 1996; Bucholz, Hesselbrock, Heath, Kramer, & Schuckit, 2000; Rasmussen et al., 2002) suggest that differences amongst individuals in symptom expression, both within a single type of externalizing disorder (e.g., substance abuse, antisocial personality disorder, smoking), as well as across different types of externalizing disorders, can be accounted for by the influence of a single underlying continuum (Brook, Ning & Brook, 2006; Elkins, King, McGue, & Iacono, 2006; Krueger, Markon, Patrick, & Iacono, 2005; Markon & Krueger, 2005; Rohde, Kahler, Lewinsohn & Brown, 2004). The fact that a single dimension of severity can explain variation both within and across externalizing disorders suggests that a common, underlying personality trait (e.g., behavioral undercontrol; Krueger et al., 2005) may account for variation in symptom severity. Thus, a great deal of evidence suggests that smoking is much like other

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types of externalizing disorders in that symptomatic differences amongst smokers appear to reflect differences of degree, not type.

The present research took a new approach to exploring the nature of nicotine dependence. Muthén & Muthén (2000) have suggested that variable- and person-centered approaches might produce complementary information. The distinction between these two general approaches can perhaps be best understood by the perspective from which they characterize the structure of a rectangular (e.g., respondent x item) data matrix. Variable-centered methods (e.g., inter-item correlation analyses, factor analysis) characterize that structure in reference to the columns (e.g., items) of the matrix, and lead to interpretations that focus on item types, and their measurement of common factors. Person-centered approaches (e.g., cluster analysis, LCA) characterize the structure in reference to the rows (e.g., respondents) of the matrix, and lead to interpretations that focus on person types.

A variable-centered approach could certainly reveal patterns of covariation amongst items that may be explained by common factors, but it is less suited to explore characteristics of the factor distributions, such as a small group of individuals having a unique pattern of symptom or scale elevations. Such would be the case if a subpopulation existed that had elevations on only those scales that were necessary for dependence.

Intrinsic to the notion of phenotypic refinement is the idea that certain core symptoms or signs are necessary and/or sufficient (Abramson et al., 1989). If a disorder has essential features, then it is possible that there exists a group of affected individuals who display such features, but not high levels of other, “optional,” or nonobligatory features. This model accords with the notion that nicotine dependent individuals tend to share many characteristics (e.g., educational status, drinking patterns, internalizing comorbidities), but some of these characteristics do not reflect necessary features of dependence.

The present research uses a person-centered approach to identify candidate symptoms or variables that may reflect core or necessary features of nicotine dependence. Candidate symptoms might be revealed by a profile of symptom elevations in a *subpopulation* of smokers, since correlations amongst core and non-core features might produce fairly uniform endorsement of symptoms amongst smokers in general. However, if strong causal mechanisms do not link features together, then it should be possible to find a group of dependent smokers who show elevations on only the necessary or core, features. In theory, such a subpopulation would be “as dependent” (would have similar status on dependence criteria) as individuals with elevations on a broader range of dependence features. That is, relations with dependence criteria would reflect status on core features for both groups; the principal difference between the groups would merely be that one group has higher levels of correlated, but inessential, features.

If the person-centered analyses do indeed uncover necessary features of dependence, then these features should meet certain criteria. For instance, if measures that capture core features of dependence really reflect the same latent variable (tobacco dependence) and they do so better than other measures, then there should be evidence from variable-centered analyses that the core features cohere statistically and they do so in a way that is consistent with the identified latent classes of smokers. Additional variable-centered analyses could be used to show that these core features of dependence are more strongly associated with nicotine dependence criteria than are other features. That is, as core features they might be especially sensitive to processes that are strongly linked to the dependence construct. If the core features are, by themselves, able to account for relations with tobacco dependence criteria, it suggests that the features are not only necessary, but sufficient, for dependence manifestation. Finally, the core or necessary features should predict dependence criteria across all smokers since they would

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reflect dependence meaningfully whether or not they are accompanied by inessential, correlated features.

The earlier findings with person-centered analyses of smoking populations showed that smokers tended to score similarly across all dependence measures (Muthén, 2006; Xian et al., 2007). These earlier findings are relevant since they suggest no group of smokers will score significantly higher on some measures than on others. However, the present research differs from most previous person-centered research on nicotine dependence in that the current research used a multifactorial measure of dependence. Previous person-centered research on nicotine dependence has used either DSM criteria or the FTND and both of these comprise few items and do not tap comprehensively the larger domain of potential dependence factors (Breteler, Hilberink, Zeeman, & Lammers, 2004; Etter et al., 1999; Haddock et al. 1999; John et al., 2004; Lessov et al., 2004; Payne, et al., 1994; Radzius et al., 2003; Radzius et al., 2004). These measures can be contrasted with new experimental measures of nicotine dependence that comprise 5 - 13 subscales: i.e., the Nicotine Dependence Syndrome Scale (NDSS; Shiffman, Waters, & Hickcox, 2004) and the Wisconsin Inventory of Smoking Dependence Motives (WISDM; Piper et al., 2004; see Table 1 for descriptions of the 13 WISDM subscales). Data indicate that some of these subscales are differentially related to important dependence criteria such as withdrawal, smoking heaviness, and relapse (Piper et al., 2006). Prior research with this instrument has not identified characteristic response patterns of subpopulations of smokers nor has it generated a factor-structure for the instrument (Piper et al., 2004). The fact that the various subscales comprised by these measures show discriminant validity with respect to different dependence criteria (Piper et al., 2006; Piper et al., 2007; Shiffman & Sayette, 2005) suggests that the DSM and FTND measures may assess a relatively impoverished range of dependence constructs. In theory, a broader range of measures should provide a greater opportunity to detect qualitatively meaningful distinctions amongst smokers as well as identification of the core features of the dependence phenotype.

The use of multidimensional scales entails a difference in type, as well as number, of constructs targeted. That is, the FTND and DSM both focus on final endpoints of dependence (e.g., heavy smoking, difficulty quitting), characteristics that all dependent smokers have in common. Thus, it follows that smokers may differ only in amount with respect to these universal features. However, it may be that smokers arrive at this “final common pathway” via different motivational routes. For instance, some smokers may smoke a lot because they are motivated to avoid or escape negative affect, while others might smoke to reduce urges. This notion is analogous to the view in molecular genetic research that, relative to global measures that tap ultimate clinical endpoints, discrete intermediate phenotypes, sensitive to underlying biological causal influences, should be more sensitive to particular genetic variants that are not shared universally by members of a diagnostic group (Baker, Conti, Moffitt & Caspi, in press; Gottesman & Gould, 2003; Meyer-Lindenberg & Weinberger, 2006). It may be that unique profiles of dependence symptoms have not arisen in previous work since most studies analyzed measures of clinical endpoints of dependence. In this regard, the WISDM-68 elicits information on relatively discrete motivational influences thought to lead to tobacco dependence. Examples of these motivational influences include incentive sensitization (Robinson & Berridge, 1993), reward (Stewart, de Wit & Eikelboom, 1984), negative reinforcement (Baker et al., 2004; Koob, 2000), and automaticity (Tiffany, 1990).

The current research employed a person-centered approach, latent profile analysis (LPA), to explore whether a latent class of smokers could be identified that shows elevations on some dependence features and not others; such patterns might suggest features that are necessary and/or sufficient for dependence. Variable-centered analyses such as exploratory factor analyses (EFAs), as well as a hybrid technique, factor mixture analysis (Lubke & Muthen, 2005), were conducted to determine if the latent structure of the dependence scales is consistent

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with both the identified core features as well as the latent class structure previously obtained. Other variable-centered analyses (e.g., logistic regressions) were then conducted to determine if measures of the core features yield stronger relations with dependence criteria than do measures of other features: i.e., they possess special meaning with regards to dependence status.

This research examined data from three randomized smoking cessation trials and one survey sample of smokers who smoked at least one cigarette in the last 14 days. We were able to conduct LPAs in all four samples, but certain validity analyses (tests of relapse relations) could be conducted only in the clinical samples where relapse and withdrawal data were gathered.

Methods

WISDM Derivation Study

Participants—775 participants (57.2% daily smokers) from Madison and Milwaukee, WI, were recruited through solicitation of participants from previous smoking cessation experiments, through newspaper and radio advertisements, and from students taking psychology classes at the University of Wisconsin-Madison (see Table 2 for demographics). Participants were at least 18 years old and they had to have smoked at least one cigarette within the last 14 days (see Piper et al., 2004 for more detail).

Procedure—Participants were invited to attend a large group survey session to complete the questionnaires and provide a breath sample for carbon monoxide measurement. During the survey session, an overview of the study was provided and participants read and signed the consent form. Participants then completed the research questionnaires. After completing the forms, the participants were given a carbon monoxide breath test and excused. Participants from the Madison and Milwaukee community received $30 in exchange for their participation. Students taking psychology classes at the University of Wisconsin-Madison received class credit in exchange for participation.

Measures—Participants completed the Preliminary Wisconsin Index of Smoking Dependence Motives (WISDM-P), which comprised 285 items designed to assess the 13 different theoretically-derived motivational domains (see Table 1). Each item is answered on a 7-point Likert scale ranging from 1 (“Not true of me at all”) to 7 (“Extremely true of me”). They also completed the FTND (Heatherton, Kozlowski, Frecker, & Fagerström, 1991), the Tobacco Dependence Screener (TDS: Kawakami, Takatsuka, Inaba, Shimizu, 1999), demographic information and a Smoking History Form. Finally, participants provided a breath sample to permit alveolar carbon monoxide analysis to verify their smoking status and estimate their smoking heaviness using a Bedfont Smokerlyzer. Results were recorded as parts per million of carbon monoxide.

Clinical Trials

Participants for all three clinical trials were recruited by media advertisements and met identical eligibility criteria. They had to be motivated to quit smoking, smoke > 9 cigarettes per day (cpd), and produce a breath sample with carbon monoxide (CO) > 9 parts per million (ppm) at baseline. Participants were excluded based on evidence of psychosis history (based on the Prime-MD structured psychiatric interview; Spitzer et al., 1994), or clinically significant depression symptoms (based on the CES-D > 16; Radloff, 1977). All participants completed several dependence assessments at a baseline visit: the FTND, the NDSS (not administered in the Quit Line study), the TDS, the WISDM, and a Smoking History Form. Data regarding smoking, medication use, positive and negative affect (PANAS; Watson, Clark, & Tellegen, 1988) and withdrawal symptoms (WSWS; Welsch et al., 1999) were collected at each study contact. All participants were called at 6 and 12 months post quit-day. Participants who reported

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seven days of abstinence at their 6- or 12-month follow-up were asked to provide a breath sample for CO analysis. According to the intent-to-treat principle (ITT), subjects who could not be located for follow-up were considered to be smoking.

Electronic Diary Study

The Electronic Diary Study comprised 463 participants (see Table 2 for participant characteristics and McCarthy et al., in press, for more detail). Enrolled smokers were randomly assigned to receive: a) Bupropion SR + individual counseling (n = 113); b) Bupropion SR + no counseling (n = 116); c) Placebo + individual counseling (n = 121); or d) Placebo + no counseling (n = 113).

Electronic diary assessments—Participants completed electronic diary (ED; Palm Vx Palmtop Computer, Palm, Inc., Santa Clara, CA, programmed by In Vivo Data, Inc., Pittsburgh, PA) entries for 2 weeks preceding, and 4 weeks following, the target quit date. Participants were instructed to complete brief (2-3 minute) ecological momentary assessment reports in response to prompts from an ED at wake-up, three to five randomly-selected times throughout the day, and at bed-time. ED assessments targeted affect, withdrawal, motivation to quit, confidence in quitting, smoking behavior, stressful events, coping, contextual cues, social support, and medication use.

Bupropion-Gum Study

The Bupropion-Gum study comprised 608 participants (see Table 2 for participant characteristics and Piper et al., 2007, for more detail). Eligible participants were randomized, in a double-blind fashion using blocked randomization within cohorts, to one of the three treatment groups: active bupropion SR (300 mg/day) + active 4-mg nicotine gum (n = 228); active bupropion SR + placebo nicotine gum (n = 224); or placebo bupropion SR + placebo gum (n = 156).

Computerized telephone assessments—Participants carried cellular phones for two weeks, centered around the quit date, to collect real-time data on withdrawal symptoms and events. They were called four times per day (once when they woke up, once before they went to bed, and two random times during the day) by an interactive phone-computer system that solicited ratings about smoking, stressors, withdrawal symptoms, and other life events.

Quit Line Study

The Quit Line study comprised 410 participants (see Table 2 for participant characteristics and Pack et al., in preparation for more detail). Enrolled smokers were randomly assigned to receive: a) Nicotine lozenge + Quit Line services (n = 106); b) Nicotine lozenge + self-help brochure (n = 101); c) Nicotine gum + Quit Line services (n = 101); or d) Nicotine gum + self-help brochure (n = 102). Ecological momentary assessment of symptoms was not used in this study.

Results

The initial analytic goal was to use LPA to characterize the profiles of obtained latent classes using Mplus 4.1 (Muthén & Muthén, 2006) and SPSS 14.0 for Windows (SPSS, Inc., 2006). For the LPA analyses, the default estimation method (maximum likelihood with robust standard errors) was used. The means of the WISDM scales were allowed to vary across classes while the variances were held equal across classes but allowed to vary across subscales. The covariances among the WISDM scales within class were fixed to zero. The analyses were conducted with each of the four data sets separately and then with all of the data combined excluding the WISDM derivation sample for the regression analyses. Final solutions were

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determined through a careful ad hoc examination of the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and entropy, as well as substantive considerations, such as class interpretability and distinctiveness.

Consideration of the model comparison criteria suggested solutions with five to seven latent classes for each of the data sets. Importantly, the 5-class solution returned a very similar result across all datasets. See Table 3 for the comparative fit indices for the 5-class solutions for all five data sets. Larger numbers of classes tended to form splinter groups based on these five classes, with the nature of the splinter groups varying somewhat across datasets. For this reason, we examined the five-class solution in each study, as well as the combined dataset.

Results of the LPAs are depicted in Figure 1a (the Bupropion-Gum study), Figure 1b (the Electronic Diary study), Figure 1c (the Quit Line study), and Figure 1d (the WISDM Derivation study). Figure 2 displays the latent class profiles for the combined data set. Figures 1 and 2 illustrate that all five data sets yielded the same basic set of profiles: Very Low, Low, Medium, High and Automatic-Atypical profiles[1] and that these were also captured in the total, combined, sample. It is important to note that all solutions yielding 5 - 7 latent profiles returned a class with a profile shape similar to that of the Automatic-Atypical profile. Solutions with more than five classes tended to splinter the five classes above into groups further distinguished by severity, for example the “Medium” class into “Medium High” and “Medium Low”, with the specific classes being splintered varying somewhat across datasets.

Inspection of the latent profiles reveals that four classes have fairly parallel profiles, indicating that they differ in severity of dependence in a way that is uniform across the dependence scales. The Automatic-Atypical profile, however, is not parallel with the others. Using 95% confidence intervals to create upper and lower bounds for the subscale means within each class profile in the combined data set, we found significant differences in means for each pair of parallel classes (Very Low, Low, Medium, and High) for each WISDM subscale, with the exception of Social/Environmental Goads. However, the Automatic-Atypical profile overlapped with the Medium profile on Automaticity, Loss of Control, Craving, Social/Environmental Goads, and Tolerance, while showing significantly lower mean scores on the other nine subscales relative to the Medium profile; in addition, it overlapped with the Low and/or Very Low profiles on Affiliative Attachment, Behavioral Choice/Melioration, Cognitive Enhancement, Cue Exposure/Associative Processes, Negative Reinforcement, Positive Reinforcement, Social/Environmental Goads, Taste/Sensory Properties, and Weight Control (see Figure 2), while showing significantly higher mean scores on the other four subscales relative to the Low and Very Low profiles. Consequently, the Automatic-Atypical group distinguishes itself by its relative elevations on the Automaticity, Loss of Control, Craving, and Tolerance subscales. The estimated percentages of smokers in each class across the four samples is as follows: Very Low (14.0%), Low, (24.8%), Medium (30.2%), High (14.0%), and Automatic-Atypical (16.9%). The percentage of smokers in the Automatic-Atypical Class was quite stable across the multiple samples.

An EFA was conducted in the combined sample to further interpret the results of the person-centered analyses and to provide a complementary perspective on the structure underlying the WISDM subscales. Correlation matrices amongst the thirteen WISDM subscales were analyzed using maximum likelihood factor analysis followed by a Promax rotation of the factor loading matrix. Eigenvalue plots combined with substantive interpretability considerations were used to identify a suitable number of factors. The EFA revealed one dominant factor

[1]The Automatic-Atypical profile was so named because it represents smoking that is frequent (heavy) and characterized by a loss of control and associated with frequent or strong urges to smoke. Since these characteristics have been associated with automatic drug use (e.g., Tiffany, 1990), we chose to characterize the distinct profile in this manner.

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(eigenvalue = 7.35) and one smaller but interpretable factor (eigenvalue = 1.23); all subsequent factors had eigenvalues at or below 1. A two-factor solution returned a standardized root-mean-square residual (SRMR) of .04, as opposed to an SRMR = .08 for the one-factor solution. Table 4 displays factor loadings following Promax rotation of the two-factor solution. Based on the eigenvalues, the first general factor accounted for a large proportion of variance in the dependence scales. However, examination of the pattern of loadings offered some support for the uniqueness of the four scales that were distinguished by the latent profile analyses. Specifically, the Automaticity, Craving, Loss of Control and Tolerance subscales constitute a first factor while the Affiliative Attachment, Behavioral Choice/Melioration, Cognitive Enhancement, Negative Reinforcement, Positive Reinforcement and Taste/Sensory Properties subscales loaded heavily on a second factor. The Cue Exposure/Associative Processes scale yields noticeably lower but moderate loadings on both factors. Despite the distinct interpretation of factors, their correlation based on Promax rotation was .69, suggesting a moderate-to-strong relationship.

When each dataset was analyzed separately, a two-factor solution was generally supported across samples -- a two-factor solution returned SRMRs of .04, .04, .07 and .05 across datasets. Most importantly, the pattern loading matrices in each dataset consistently identified the four subscales of Automaticity, Craving, Loss of Control and Tolerance as primary indicators of a distinct factor under a two-factor solution.

In summary, the person-centered and variable-centered analyses both distinguished the same two subscale types, one type with four, and the other type with nine, subscales. The two forms of analysis provide a complementary picture of the meaningfulness of this distinction in understanding between-smoker heterogeneity. The variable-centered analysis (i.e., EFA) showed that the four scales highlighted in the between-persons analyses did indeed show greater intercorrelations with one another than they did with the other nine WISDM scales. The person-centered analyses (i.e., LPAs) showed that the distinguishability of these scales can largely be attributed to a latent class of smokers who show relative elevations on these same four scales.

To further confirm the distinguishability of classes according to unique factor distributions, we next applied a factor mixture analysis (FMA; Muthen & Asparpouhov, 2006) to both the combined dataset and separate datasets. The FMA model assumes the same two-factor structure revealed in the EFA, but also assumes that respondents belong to latent classes that define how the factors are distributed. Specifically, the model assumes each latent class has a potentially different mean for each factor; for the current analysis, the factor variances were assumed constant across classes, but varied between factors. In this way, the current application of FMA can be viewed as a two-factor model with a nonparametric distribution of factors as opposed to the normally distributed factors assumed in EFA.

An additional advantage of FMA is its capacity to account for some within-class heterogeneity related to the factors. Due to the presence of several well-ordered severity classes in the latent profile analyses, FMA was considered useful in the current application as a tool for potentially reducing the total number of classes and further confirming that the class elevated on the Automaticity, Loss of Control, Craving, and Tolerance subscales, relative to the other subscales, appeared as such due to its elevation on the common factor underlying these subscales. Table 5 displays information criteria and entropy values for the FMA solutions across varying numbers of classes in both the four separate datasets and the combined dataset. The information criteria tend to minimize around four classes across datasets. It should be noted that 6-class solutions in both the separate datasets and the combined dataset consistently failed to converge due to the emergence of a class with zero frequencies. (This also occurred for the 5-class FMA solution in the Electronic Diary study.) Evidence supporting fewer classes

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than in the LPA solutions may be attributed to the allowance of some within-class variability of severity in each class. Under a one-factor model, mixture factor solutions of six classes were found to return the lowest AIC (= 96961) and BIC (= 97241), although both index values were considerably higher than those observed for the optimal two-factor solutions, again supporting the presence of two distinct factors.

Of chief importance is the retention and consistent emergence of a class elevated on the first factor (as labeled in Table 6). Figures 3a-3d plot for each of the four datasets the estimated mean score for each of the 13 subscales, analogous to Figures 1a-1d of the LPA, as defined by the factor mean, subscale factor loading, and subscale intercept estimates for each class. Despite small variability across datasets in the absolute elevation of the Automatic-Atypical class, the continuing presence of the same unique class as obtained in the LPAs is apparent from the relative elevation on the Automaticity, Loss of Control, Craving, and Tolerance subscales for a single class in each dataset. Datasets for which information criteria were reduced beyond four classes essentially introduced additional severity classes while maintaining the presence of the Automatic-Atypical class. Table 6 displays results for the four-class FMA solution. The left-hand columns contain estimates for the factor solution, while the right-hand columns contain parameter estimates related to the latent classes. The loading estimates for the factor solution resemble (up to a rescaling of the factor) those observed for the two-factor EFA solution. Consistent with the LPA, three of the classes can be clearly ordered with respect to their expected scores across WISDM subscales, while one class (the Automatic-Atypical class) displays factor means that result in elevated subscale scores on the primary subscales related to Factor 1. (Note that in FMA, the factor mean estimates themselves are not enough to characterize the relative elevations of the classes on the thirteen subscales, as these are also affected by the subscale factor loadings and subscale intercepts).

The FMA thus confirms the interpretation given to the combined person-centered (LPA) and variable-centered analyses (EFA). It also yields consistently better fit criteria than the LPA analyses, a result that can be attributed both to FMA's allowance for within-class heterogeneity in dependence severity as well as the lower penalty for the addition of classes, which now entail only two additional parameters per class (two factor means) as opposed to the thirteen additional parameters (thirteen subscale means) added through LPA. As the one-class FMA solution is essentially a two-factor model in which the pattern of loadings from the EFA is imposed, the superiority of the fit criteria for the multiple-class FMAs in comparison to the single-class FMA also lends support to nonparametric factor distribution that emerged in the multiple-class FMA solutions as opposed to the bivariate normal factor distribution of the one-class solution. Our consistent finding of a unique class elevated on the first factor would appear to explain this lack of normality.

The WISDM Automaticity, Tolerance, Craving and Loss of Control subscales may have special significance in that relative elevations on just these four subscales consistently identify a unique smoker latent class that is based on preferential loadings on a distinct factor. The Automatic-Atypical profile generated by the relative elevations on these scales and the EFA results do not, however, by themselves permit strong inference as to the significance or meaning of these scales. The subsequent analyses were intended to determine whether the four scales in question had special significance for nicotine dependence.[2] We hypothesized that scores on the four WISDM scales in question (Automaticity, Craving, Loss of Control, and Tolerance; hereafter designated “primary” scales) would: (1) show significant relations with dependence criteria; and (2) show stronger predictive relations than do the other WISDM scales (i.e., the secondary scales) when both are entered into prediction models. In addition to the prediction of criteria, we also examined the relation of primary and secondary scales to comorbid conditions and environmental factors that might be related with criteria (e.g., household smoking restrictions).

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In the subsequent analyses, the primary scale score is an average of the four targeted subscale scores (Automaticity, Craving, Loss of Control and Tolerance; for the combined data set: range = 1-7, M = 4.93, SD = 1.17, α for 18 items = .85, α for 4 subscales = .82), while the secondary scales score is an average of the scores of the other nine subscales (Affiliative Attachment, Behavioral Choice/Melioration, Cognitive Enhancement, Cue Exposure/Associative Processes, Negative Reinforcement, Positive Reinforcement, Social/Environmental Goads, Taste/Sensory Properties, and Weight Control; for the combined data set: range = 1-7, M = 3.73, SD = 1.06, α for 50 items = .95, α for 9 subscales = .85). These results suggest that scores on the primary scales tended to be higher than scores on the other subscales.

In an attempt to understand the construct validity of the primary scales as compared with the secondary scales, we conducted a series of regression analyses (both linear and logistic) in which primary and secondary scales were related to dependence criteria and important person factors. With respect to the withdrawal analyses, each respondent considered in these analyses (i.e., participants in the Electronic Diary and Bupropion-Gum studies) provided daily reports of withdrawal symptoms for a week following a quit attempt. Based on these daily reports, the increase in withdrawal on the quit day and the post-quit slope of withdrawal could be estimated using a hierarchical random slope and intercept model fit using the software program HLM. In this model, the random intercept (interpretable as change in withdrawal symptoms on the quit day) and slope (interpretable as average daily change in withdrawal symptoms post-quit) could be estimated for each individual using Empirical Bayes' estimates.

In the first set of analyses, the primary scales score was used as an independent variable in univariate models to predict other tobacco dependence measures, demographic variables and environmental variables. Including treatment as a covariate (active vs. placebo medication) did not change the prediction of relapse or craving. Results revealed that the primary scales score significantly predicted numerous tobacco dependence measures and criteria (e.g., FTND, cigarettes smoked per day, increase in withdrawal on the quit day, 1-week and 6-month abstinence) as well as some individual difference variables (smoking restrictions in the home, alcohol problems; see Tables 7 and 8).[3] The secondary scales also predicted abstinence at 1 week as well as other outcomes (see Tables 7 and 8), although the secondary scales score did not predict long-term abstinence, baseline CO, age, age began daily smoking, number of previous cessation attempts, alcohol problems or education. It is the case that even when the secondary scales significantly predicted dependence measures, the primary scales yielded stronger predictive relations (see Table 7). The one exception to this pattern is in the prediction of post-cessation craving, where the secondary scales generated stronger predictions.

When the primary and secondary scales scores were entered together in multivariate regression analyses, the primary scales score continued to predict multiple smoking and individual difference variables. In fact, when both variables were entered into analyses, the secondary scales score variable no longer predicted 1-week abstinence (Table 8).[4] Interestingly, the directionality of the relation between the secondary scale score and dependence criteria was

[2]The representation of hypotheses in the variable-centered form, rather than the person-centered form (e.g., via posterior probabilities), was considered important for two reasons. One is that the class membership is based upon relative scale elevation (primary vs. secondary scales) and our hypothesis was that it was absolute elevation of the primary scales that would be most predictive of dependence criteria. Thus, the posterior probabilities for membership in the Automatic-Atypical class, from the person-centered analyses, would not reflect accurately actual level of endorsement of the primary scales. Second, the use of posterior class membership probabilities, a typical approach in person-centered analyses, has limitations when studied in relation to other variables, in particular, the inability to account for the ordering of the classes in terms of level of dependence. As several of the classes are ordered, it was anticipated that a person-centered analysis would have reduced power if forced to study class membership in relation to the external dependence criteria.

[3]Structural models yielded similar results with Factor 1, the factor upon which the primary scales loaded, showing stronger prediction of criteria than did Factor 2.

[4]Two of the secondary scales (Social/Environmental Goad and Cue Exposure/Associative Processes) had relatively low loadings on the EFA Factor 1. Therefore, we conducted all of the validation regression analyses using only the 7 secondary scales that did load onto EFA Factor 1. Results were highly similar to those yielded with the full 9 secondary scales.

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often anomalous when it was co-entered with the primary scales score: i.e., its direction was often opposite to that of a putative dependence measure. This was likely because the primary scales score variable functioned as a suppressor. That is, in many cases, it accounted for most of the predictive validity of the secondary scales variable, and the residualized secondary scales variable was then negatively related to the dependent variables.

Neither the primary scale score nor the secondary scale score were related to problems with other drugs, problems with depression, or change in craving over the first week post-quit (data not shown).

Discussion

The present results suggest a possible route for the refinement of the nicotine dependence phenotype. The LPAs revealed a remarkably consistent pattern in which one latent class showed relative elevations of four dependence scales (Automaticity, Craving, Loss of Control and Tolerance). For this latent class, in each of four samples it was the same four scales, and never the other nine scales, that were relatively elevated. This observation suggested that these four scales might cohere to index a somewhat distinct dimension of dependence; it also raised the possibility that elevations on just these four scales are enough to produce significant tobacco dependence (i.e., yield strong relations with dependence criteria). Factor analyses then showed that these four primary scales did indeed form a somewhat distinct dimension of dependence. Factor mixture modeling showed that latent class status was related to the factor distribution as three of the latent classes could be effectively ordered by both factors, with one additional class showing relative elevations on only a factor primarily defined by the four subscales. In addition, the factor mixture models showed strong confirmation across all four samples of the presence of a unique latent class whether four or five classes of smokers were extracted; amongst these classes, and in all four samples, one FMA profile essentially reproduced the profile of the Automatic-Atypical class generated by the latent profile analysis.[5] Finally, regression analyses showed that the primary scales, in contrast to the secondary scales, tended to have stronger predictive relations with dependence criteria (e.g., abstinence status, carbon monoxide levels, other dependence assays; see Tables 7 & 8). In fact, these analyses revealed that the secondary scales tended to have little predictive validity once the primary scales were entered into the prediction models. So, the evidence shows that: there is a profile pattern across all scales that is not reducible to severity per se, this result is replicable, the profile differences are of meaningful significance or magnitude, the differences are related to the factor structure of dependence, and this pattern is consequential (it highlights the features of dependence that are most predictive of dependence criteria).

The evidence suggests that if smokers are high in the motives tapped by the primary scales they will show relatively high scores on dependence criteria, and that their standing on other dependence scales or motives, as indexed by the secondary scales, will contribute relatively little to the strength of their dependence. Therefore, the configural shape of the Automatic-Atypical profile may not suggest a unique intensity of dependence, but rather a difference in the refinement or purity of motives. Further, the fact that secondary scale scores add little to the prediction of dependence criteria, suggests that the features tapped by the primary scales may be sufficient for dependence manifestation. For example, if smokers report smoking because of craving and because smoking has become automatic, then it should matter little if they also say they smoke to reduce negative moods, to experience pleasure, or because external cues strongly trigger their smoking.

[5]The fact that four or five classes could be identified across the samples via the factor mixture models is not of concern since these merely reflect the different parsing of the individuals whose data could be best explained along a severity dimension. All of the models contained a "unique" class and none contained any other configural class.

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The current findings raise two questions; the first is why the four primary scales, in particular, tend to show relative elevations; the second is whether the constructs targeted by these four scales offer any insight into the nature of tobacco dependence.

It is possible that the primary scales tap motives that are not only sufficient to yield nicotine dependence, but also necessary. The unique profile generated by the primary scales may occur because they tap core, obligatory features of dependence and that other features are correlated, but "optional." This situation is analogous to what one would find in conditions that are manifest in a primary set of signs or symptoms that are uniformly present in severe cases, but that may or may not also present with auxiliary symptoms. An example of this might be a condition such as celiac disease, a condition that may present with highly diverse symptoms and signs. Not all individuals present with the same constellation of symptoms/signs (i.e., some people have headache, fatigue, anemia). However, there is a core set of primary symptoms/signs that tends to be present consistently in severe forms of this disorder (e.g., IgA endomysial antibodies, IgA tissue transglutaminase, and gastro-intestinal enteropathies). Not all sufferers will experience such auxiliary conditions as hypothyroidism and headache, but all those with severe cases will have the primary signs/symptoms. This would, in theory, permit that existence of a class of sufferers who have high levels of "obligatory," or primary, symptoms, but generally modest levels of "optional," or secondary, symptoms. Thus, amongst strongly dependent smokers, if one group of scales were to be uniquely and especially elevated, it would be the primary scales.[6] The importance of the findings arises, in part, from the fact that the secondary scales served as meaningful, worthy competitors. The motives tapped by the secondary scales have been theoretically and empirically linked to dependence.

Obviously the data do not permit definitive conclusions about whether the dimensions targeted by the primary scales represent necessary or sufficient features of tobacco dependence. For instance, it is certainly possible that some smokers may have a tendency to relapse back to smoking and smoke at high rates, without scoring highly on the primary scales. The current results might, nevertheless, provide useful guidance in future attempts to refine the phenotype.

Both the LPA and EFA detected dependence scales that index an important dimension of tobacco dependence. However, this does not tell us, specifically, why some individuals rated the primary scales relatively highly, while others did not. There are at least two basic reasons that some individuals' ratings may have conformed to the profile generated by the Automatic-Atypical class. One reason might be that for such individuals only the primary motives are, in fact, present to a significant degree. That is, these individuals do not find that smoking quells negative affect or that it produces pleasure. The only features that are present to a significant degree are craving/craving control, smoking automatically, and so on. A second reason might be that these secondary motives or features might be present for the Automatic-Atypical latent class of smokers, but that they recognize that such motives are not central or critical to their drug use. Thus, on the one hand, the data might reflect actual presence of the dependence features, and on the other hand, the data might reflect the individual's judgment or evaluation of importance[7]. Either one of these possibilities is compatible with the notion that the primary scales tap core dependence motives, and the data do not currently permit strong inferences regarding these two possibilities.

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[6]The WISDM Derivation sample, depicted in Figure 1d, contained a large number of light smokers. It is interesting that in the Low and Very Low classes in that sample the secondary scales were endorsed somewhat more highly than the primary scales. This accords with the observation that secondary motives for smoking may be more important for those who are not significantly dependent (see Piper et al., 2004).

[7]The flip side of the discrimination argument is that individuals conforming to a non-Automatic-Atypical profile (who endorse all scales or motives similarly) are unable or disinclined to discriminate amongst the scales. However, this does not mean that their ratings were intrinsically inaccurate since their endorsement of the primary scales carried considerable predictive information relative to the dependence criteria.

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Regardless of the reason that smokers characterized by the Automatic-Atypical profile preferentially endorsed the primary scales, the relative elevation of these scales fits with other recent data in the field. There is a variety of evidence that as addiction becomes entrenched, control over smoking is shifted from cognitive control systems to automatic motor control systems that execute self-administration without such control, and perhaps, without awareness (Baker, Piper, McCarthy, Majeskie & Fiore, 2004; Curtin, McCarthy, Piper & Baker, 2006; Tiffany, 1990; TTURC Tobacco Dependence Phenotype Workgroup, 2007). Thus, as smoking becomes ubiquitous and automatic, smokers may believe that it has become noncontingent with instrumental uses and external and internal stimuli -- and to some extent it actually has become so. Conversely, there is evidence that "chippers," or smokers who are not dependent, are more likely to report smoking in relation to setting events or cues (Shiffman & Paty, 2006). There is considerable basic behavioral and neuropharmacologic research that supports the notion that addiction involves a shift from instrumental, goal-driven behavior, to automatized, habitual response patterns. As Everett and Robbins (2005) note in a recent, influential review:

> "In theoretical terms, it seems reasonable to characterize such compulsive behavior as a maladaptive stimulus-response habit in which the ultimate goal of the behavior has been devalued so that the behavior is not directly under the control of the goal.... Rather, responding is governed by a succession of discriminative stimuli, which also function—when they are presented as a consequence of instrumental responses—as conditioned reinforcers. Hypothetically, such stimulus-response associative ('habit') learning occurs in parallel with instrumental action-outcome learning but, with extended training, eventually dominates behavioral output" (p. 1485).

Thus, the Automatic-Atypical group of smokers may represent individuals who are simply more aware that their drug use is driven by automatic processes and that it is somewhat divorced from the consequences of use.

The results also suggest that urges or cravings are important manifestations of significant dependence. This is compatible with the notion that as addictive behavior becomes automatic, urges are caused by a blockade of the automatized drug self-administration sequence (Curtin et al., 2006; Tiffany, 1990). Thus, the role of automaticity and the importance of urges may reflect complementary features of dependence (Tiffany, 1990).

It may be that these two features of dependence, automaticity and craving, are related to smokers' feelings of loss of control. If smokers frequently experience strong urges when they go without smoking for a short period of time or if they realize that their smoking occurs automatically without any conscious direction, they may be more likely to report that they do not have control over their smoking.

At first blush one might interpret these results as being in conflict with theories that emphasize such mechanisms as positive reinforcement, negative reinforcement, or even cue-controlled incentive processing (e.g., Baker et al., 2004; Robinson & Berridge, 1993). However, this conflict may be more apparent than real; such mechanisms may still be critical to the development and maintenance of addiction. For some dependent tobacco users the information processing supporting those motives may have become opaque (e.g., Baker et al., 2004). In addition, motives tapped by secondary scales may play a significant role at an early point in the development of dependence. Also, some of these motives (e.g., Taste/Sensory Properties; Cannon et al., 2005) have been linked with genetic variants that may contribute to dependence, even if not serving as a sensitive index.

Several caveats should be mentioned in closing. First, while the primary WISDM scales provide some insight into what may constitute necessary and sufficient features of tobacco

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dependence, they are not necessarily the best measures of that construct. These scales may provide superior insight into the nature of the construct, but other scales tapping the same construct may yield stronger predictions of dependence criteria such as relapse (e.g., Heatherton et al., 1991; TTURC Nicotine Dependence Phenotype Working Group, 2007). Second, while we did use confirmatory factor mixture models to examine the class-factor relations hypothesized, the models were estimated on the same samples that generated the exploratory latent class models. However, the fact that the same basic results were obtained across all four samples quells concern that sampling error contributed to these results. Third, the current results do not imply the presence of a type of smoker who is uniquely dependent; it does not imply the existence of a dependence taxon. After all, the data suggest that the same primary scales features characterize dependence for all smokers. If anything, the current data would be more consistent with a dimensional model of dependence such that all smokers could be ordered in dependence along a severity dimension if that dimension were based only on the primary scales. However, no strong claims on this topic are possible since it is extremely difficult to arrive at firm conclusions with regards to dimensionality vs. taxonicity even with specialized statistical procedures (e.g., see De Boeck, Wilson, & Acton, 2005; Golden & Mayer, 1994). Moreover, as Haslam and Kim (2002, p.311) note, “matters of kind and matters of degree, itself [might] be a matter of degree” (see De Boeck, Wilson, & Acton, 2005). This admonition also warns us that it may be best to view even concepts such as “necessary and sufficient” in relative versus absolute terms. Finally, the data upon which this paper is based do not arise from population-based samples. Therefore, the generalizability of the present results may be questioned. Finally, self-report measures were used to assess dependence motives; some dependence motives may not be well captured by such a measurement strategy and this might have biased the pattern of associations found with the various motives.

Conclusions

A multidimensional assessment of tobacco dependence motives that focused on relatively specific mechanisms of dependence revealed a latent class of smokers that was distinguished by relative endorsement of a small number of smoking motives. Specifically, this class was distinguished by relative endorsement of Automaticity, Craving, Loss of Control, and Tolerance motives for smoking. Other latent classes of smokers showed similar levels of endorsement across all the motive types. The finding of relative elevations of particular scales suggested that these scales might tap a distillation of dependence motives or features: a group of features that might be necessary and sufficient for the manifestation of other signs of tobacco dependence. Analyses showed that this group of the four scales, dubbed primary scales, was consistently related to key nicotine dependence criteria such as an inability to remain abstinent from smoking. The nature of the primary scales suggests that core elements of tobacco (smoking) dependence are: smoking that is no longer under conscious control, smoking that is heavy and pervasive, and the occurrence of strong frequent cravings.

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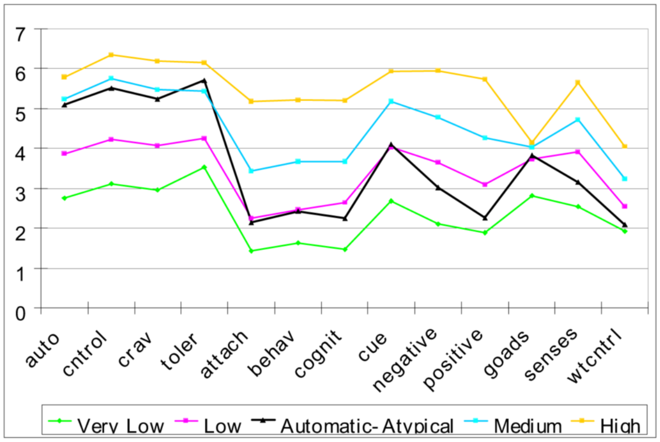

Figure 1a. Bupropion-Gum Study

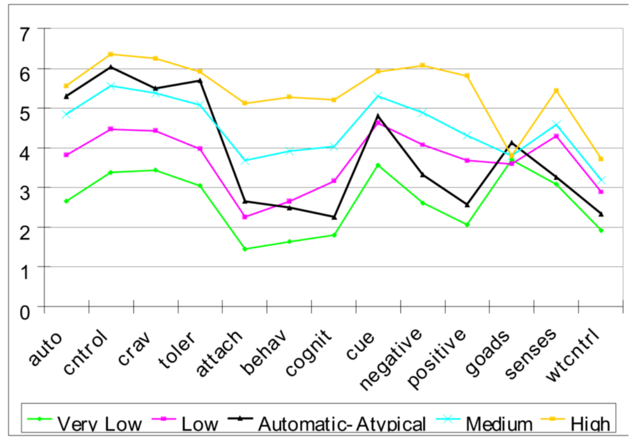

Figure 1b. Electronic Diary Study

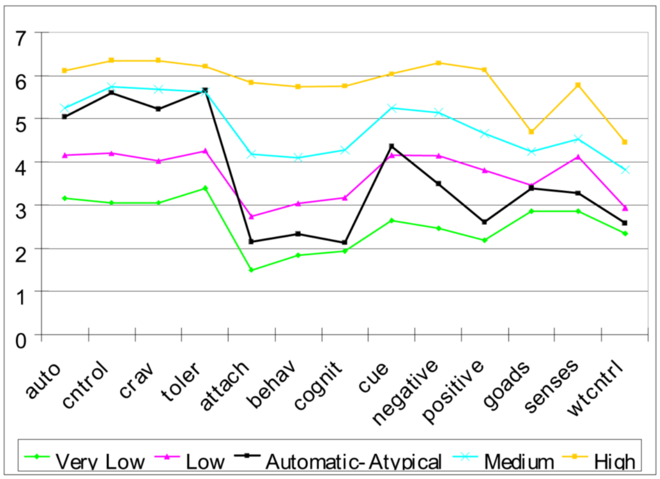

Figure 1c. Quit Line Study

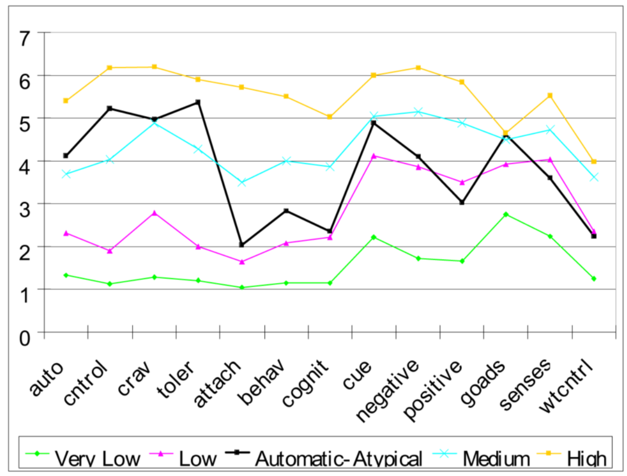

Figure 1d. WISDM Derivation Study

Figure 1.

This figure represents the 5 latent classes derived from the four independent studies. For 1a, the Bupropion-Gum study, the posterior probabilities for each class were: High (15.1%), Medium (35.2%), Automatic-Atypical (24.8%), Low (15.1%) and Very Low (9.1%). For 1b, the Electronic Diary study, the posterior probabilities for each class were: High (15.6%), Medium (24.2%), Automatic-Atypical (14.5%), Low (30.5%) and Very Low (15.3%). For 1c, the Quit Line study, the posterior probabilities for each class were: High (15.9%), Medium (33.4%), Automatic-Atypical (16.1%), Low (23.4%) and Very Low (11.2%). For 1d, the WISDM Derivation study, the posterior probabilities for each class were: High (11.7%), Medium (17.9%), Automatic-Atypical (9.1%), Low (27.6%) and Very Low (33.7%). Auto = Automaticity, Cntrol = Loss of Control, Crav = Craving, Toler = Tolerance, Attach = Affiliative Attachment, Behav = Behavioral Choice/Melioration, Cognit = Cognitive Enhancement, Cue = Cue Exposure/Associative Processes, Negative = Negative Reinforcement, Positive = Positive Reinforcement, Goads = Social/Environmental Goads, Senses = Taste/Sensory Processes, Wtcntrl = Weight Control.

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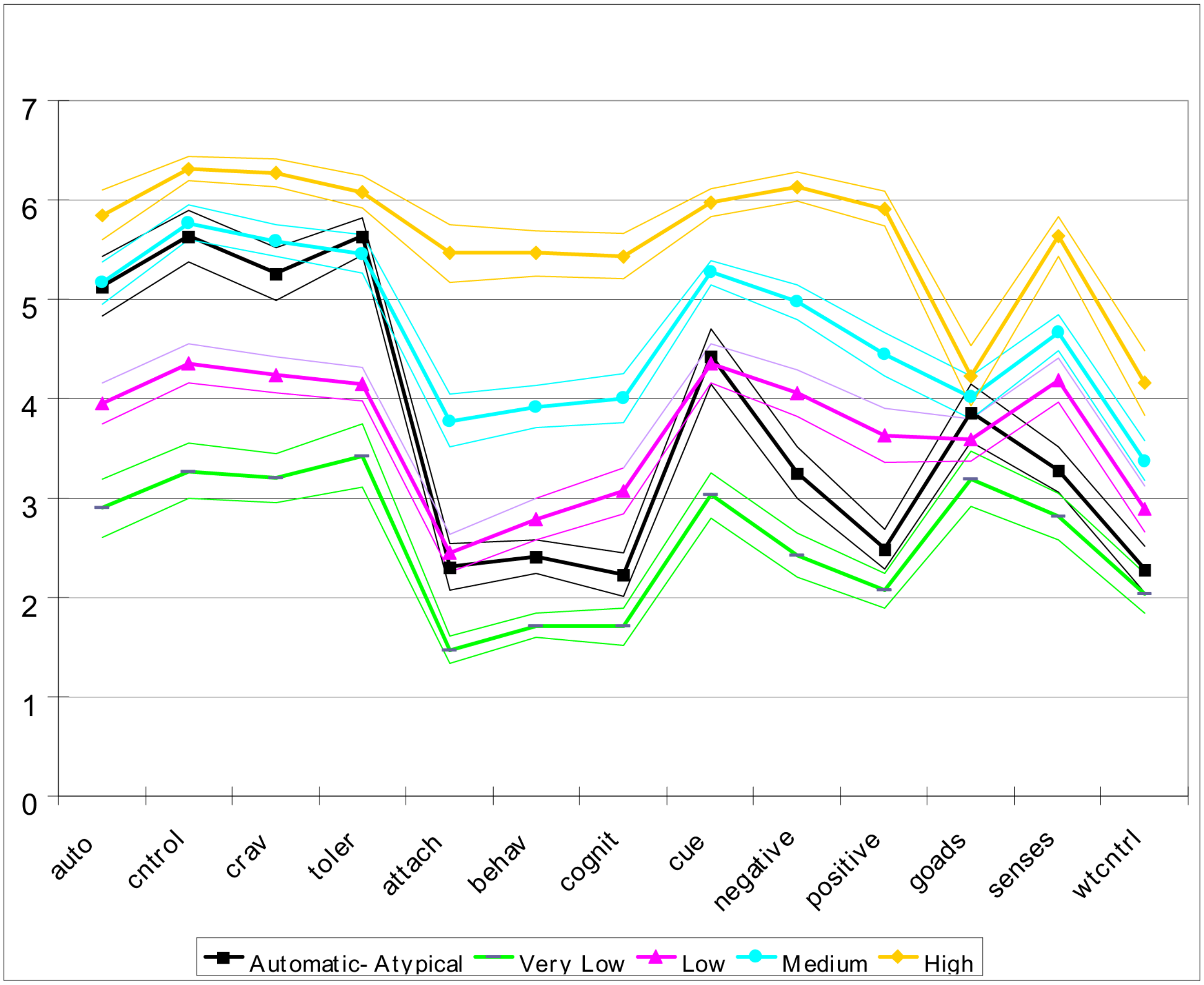

Figure 2.
This figure represents the 5 latent classes derived from the combined dataset with the 95% confidence intervals. The posterior probabilities for each class were: High (14.0%), Medium (30.2%), Automatic-Atypical (16.9%), Low (24.8%) and Very Low (14.0%). Auto = Automaticity, Cntrol = Loss of Control, Crav = Craving, Toler = Tolerance, Attach = Affiliative Attachment, Behav = Behavioral Choice/Melioration, Cognit = Cognitive Enhancement, Cue = Cue Exposure/Associative Processes, Negative = Negative Reinforcement, Positive = Positive Reinforcement, Goads = Social/Environmental Goads, Senses = Taste/Sensory Processes, Wtcntrl = Weight Control.

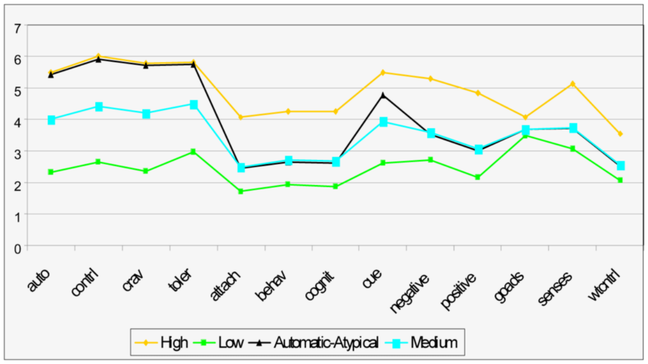

Figure 3a. Bupropion-Gum Study

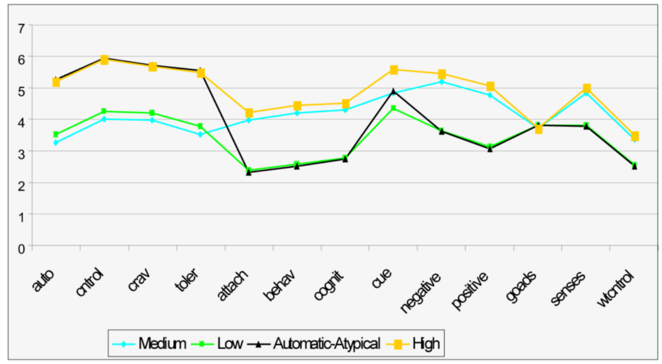

Figure 3b. Electronic Diary Study

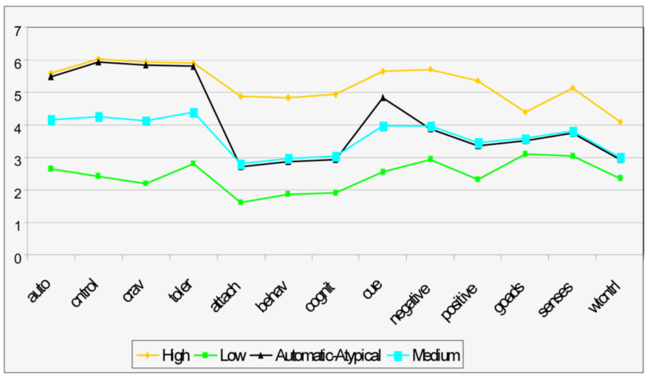

Figure 3c. Quit Line Study

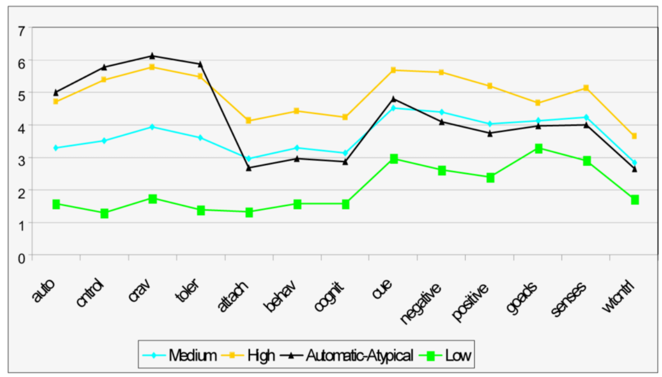

Figure 3d. WISDM Derivation Study

Figure 3.

a. This figure represents the four FMA latent classes derived from each of the independent data sets. For 3a, the Bupropion-Gum study, the posterior probabilities for each class were: High (35.1%), Medium (38.6%), Automatic-Atypical (19.7%), and Low (6.6%). For 3b, the Electronic Diary study, the posterior probabilities for each class were: High (28.7%), Medium (3.5%), Automatic-Atypical (19.9%), and Low (47.9%). For 3c, the Quit Line study, the posterior probabilities for each class were: High (37.9%), Medium (39.4%), Automatic-Atypical (19.1%), and Low (3.7%). For 3d, the WISDM Derivation study, the posterior probabilities for each class were: High (19.5%), Medium (21.0%), Automatic-Atypical (6.2%), and Low (53.3%). Auto = Automaticity, Cntrol = Loss of Control, Crav = Craving, Toler = Tolerance, Attach = Affiliative Attachment, Behav = Behavioral Choice/Melioration, Cognit = Cognitive Enhancement, Cue = Cue Exposure/Associative Processes, Negative = Negative Reinforcement, Positive = Positive Reinforcement, Goads = Social/Environmental Goads, Senses = Taste/Sensory Processes, Wtcntrl = Weight Control.

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Table 1

WISDM Subscale Descriptions

Subscale (Number of items)	Target construct
Affiliative Attachment (5)	Characterized by a strong emotional attachment to smoking and cigarettes
Automaticity (5)	Characterized by smoking without awareness or intention
Control (4)	Based on the notion that once dependence becomes ingrained, the dependent person believes that he or she has lost volitional control over drug use
Behavioral Choice/Melioration (7)	Characterized by smoking despite constraints on smoking or negative consequences and/or the lack of other options or reinforcers
Cognitive Enhancement (5)	Characterized by smoking to improve cognitive functioning (e.g., attention)
Cravings (4)	Characterized by smoking in response to craving or experiencing intense and/or frequent urges to smoke
Cue Exposure/ Associative Processes (7)	Characterized by frequent encounters with nonsocial smoking cues or a strong perceived link between cue exposure and the desire or tendency to smoke
Negative Reinforcement (6)	Characterized by the tendency or desire to smoke in order to ameliorate negative internal states
Positive Reinforcement (5)	Characterized by the desire to smoke in order to experience a “buzz” or a “high,” or to enhance an already positive feeling or experience
Social/ Environmental Goads (4)	Characterized by social stimuli or contexts that either model or invite smoking
Taste/Sensory Properties (6)	Characterized by the desire or tendency to smoke in order to experience the orosensory/gustatory effects of smoking
Tolerance (5)	Characterized by the principal need of individuals to smoke increasing amounts over time in order to experience the desired effects, or the ability to smoke large amounts without acute toxicity
Weight Control (5)	Characterized by the use of cigarettes to control body weight or appetite
Total (68)	

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Table 2

Demographics

	Total (without WISDM Derivation) (N=1481)	Electronic Diary (n=463)	Bupropion-Gum (n=608)	Quit Line (n = 410)	WISDM Derivation (n = 775)
Women (%)	809 (54.6)	233 (50.3)	352 (57.9)	224 (54.6)	456 (60.0)
White (%)	1144 (77.2)	414 (89.4)	449 (73.8)	281 (68.5)	640 (82.3)
Black (%)	257 (17.4)	25 (5.4)	130 (21.4)	102 (24.9)	83 (10.7)
High school education or more (%)	1354 (91.4)	441 (95.2)	549 (90.3)	364 (88.8)	724 (93.1)
Married (%)	624 (42.1)	198 (42.8)	283 (46.5)	143 (34.9)	92 (11.9)
Age (SD)	41.05 (11.94)	38.76 (12.16)	41.78 (11.34)	42. 57 (12.22)	29.83 (14.11)
Mean cigarettes per day (SD)	22.46 (10.05)	21.93 (10.44)	22.44 (9.87)	23.11 (9.86)	10.53 (10.71)
Baseline CO in ppm (SD)	26.36 (11.35)	24.51 (11.80)	27.11 (11.69)	27.35 (11.54)	10.82 (10.13)

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Table 3

Comparative Fit indices for the 5 latent profile solutions for all 5 data sets

Data Set	Number of classes	AIC	BIC	Entropy
Electronic Diary Study	5	19150	19490	0.862
	6	19052	19450	0.865
	7	19007	19462	0.853
Bupropion-Gum Study	5	25217	25578	0.863
	6	22582	23005	0.724
	7	22544	23029	0.755
Quit Line Study	5	17249	17579	0.888
	6	17152	17538	0.899
	7	17070	17512	0.902
WISDM Derivation Study	5	31419	31800	0.944
	6	31078	31525	0.943
	7	30797	31309	0.936
Merged Data	5	95263	95732	0.903
	6	94556	95105	0.888
	7	93695	94325	0.888

AIC = AIkike information criterion (smaller indicates better fit), BIC = Bayes information criterion (smaller equals better fit), Entropy = indicates how well the model predicts class memberships or factor scores; the closer to 1 the better.

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Table 4

Promax rotated factor loadings from the exploratory factor analysis with the combined sample (n = 2257; interfactor correlation = .69)

WISDM Scale	Factor 1	Factor 2
Affiliative Attachment	.26	.59
Automaticity	.78	.00
Loss of Control	.92	-.02
Behavioral Choice/Melioration	.23	.70
Cognitive Enhancement	.13	.68
Craving	.75	.19
Cue Exposure/Associative Processes	.34	.50
Negative Reinforcement	.02	.88
Positive Reinforcement	-.18	1.04
Social/Environmental Goads	.12	.15
Taste and Sensory Processes	-.06	.74
Tolerance	.94	-.08
Weight Control	.10	.41

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Table 5

Comparative Fit indices for the factor mixture analyses for all 5 data sets

Data Set	Number of classes	AIC	BIC	Entropy
Electronic Diary Study	1	18983	19152	--
	2	18969	19151	.606
	3	18951	19146	.565
	4	18949	19156	.669
	5	NA	NA	.729
Bupropion-Gum Study	1	24811	24992	--
	2	24785	24979	.637
	3	24759	24967	.558
	4	24735	24955	.671
	5	24738	24972	.685
Quit Line Study	1	16916	17081	--
	2	16894	17071	.676
	3	16863	17051	.639
	4	16841	17042	.755
	5	16842	17055	.768
WISDM Derivation Study	1	31756	31947	--
	2	31500	31705	--
	3	31367	31586	.867
	4	31293	31526	.874
	5	31256	31503	.856
Merged Data	1	94385	94620	--
	2	93909	94161	.832
	3	93779	94048	.675
	4	93596	93883	.734
	5	93531	93834	.744

AIC = AIkike information criterion (smaller indicates better fit), BIC = Bayes information criterion (smaller equals better fit), Entropy = indicates how well the model predicts class memberships or factor scores; the closer to 1 the better.

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Table 6

Factor mixture analysis, four class two-factor solution

	Two-Factor Solution				Factor Distribution			
WISDM Subscale	**Factor 1**	**Factor 2**	**Intercept**	**Resid Variance**	**Latent Class***	**Factor 1 Mean**	**Factor 2 Mean**	**Proportion**
Attach	--	1.00	2.59	.98	High	.04	1.89	.24
Behav	--	.97	2.81	.42	Low	-1.20	-1.21	.22
Cognit	--	.96	2.83	1.13	Med	-.47	.11	.35
Cue	1.00	.51	4.72	.90	Automatic-Atypical	.00	.00	.19
Neg Reinf	--	.99	3.82	.65				
Pos Reinf	--	.99	3.40	.62				
Soc/Env Goads	--	.32	3.71	3.37				
Senses	--	.75	3.84	1.36				
Weight Control	--	.63	2.63	2.42				
Auto	3.03	--	5.24	1.53				
Control	3.63	--	5.83	.73				
Craving	3.27	--	5.72	.61				
Toler	3.44	--	5.67	.88				

*Each latent class has a common factor 1 variance (.07), factor 2 variance (.71), and factor 1, factor 2 covariance (.21).

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Table 7

Linear regressions using the Primary Motives, Secondary Motives and Primary Motives to WISDM ratio to predict continuous variables

Dependent variable	Analysis	Predictor	B	SE	β	t
FTND	Univariate	Primary	.19	.01	.60	28.65**
	Univariate	Secondary	.11	.01	.30	12.03**
	Multivariate	Primary	.21	.01	.66	25.21**
		Secondary	-.04	.01	-.10	-3.74**
TDS	Univariate	Primary	.06	.004	.36	14.95**
	Univariate	Secondary	.07	.01	.35	14.24**
	Multivariate	Primary	.04	.01	.24	8.03**
		Secondary	.04	.01	.10	6.75**
Cigarettes per day	Univariate	Primary	3.42	.21	.40	16.61**
	Univariate	Secondary	1.63	.24	.17	6.70**
	Multivariate	Primary	3.97	.26	.46	15.46**
		Secondary	-1.02	.28	-.11	-3.58**
Baseline CO	Univariate	Primary	2.45	.25	.25	9.88**
	Univariate	Secondary	.51	.28	.05	1.80
	Multivariate	Primary	3.41	.31	.35	11.07**
		Secondary	-1.76	.34	-.16	-5.19**
Quit day increase in craving	Univariate	Primary	.83	.09	.25	9.02**
	Univariate	Secondary	1.14	.10	.32	11.47**
	Multivariate	Primary	.32	.11	.10	2.88**
		Secondary	.92	.12	.26	7.45**
Age	Univariate	Primary	1.53	.26	.15	5.84**
	Univariate	Secondary	.41	.29	.04	1.38
	Multivariate	Primary	2.07	.33	.20	6.30**
		Secondary	-.98	.36	-.09	-2.71**
Age of initiation	Univariate	Primary	-.30	.09	-.09	-3.39**
	Univariate	Secondary	-.22	.10	-.06	-2.26*
	Multivariate	Primary	-.28	.11	-.08	-2.53*
		Secondary	-.04	.12	-.01	-.29
Age began smoking daily	Univariate	Primary	-.37	.09	-.11	-4.16**
	Univariate	Secondary	-.18	.10	-.05	-1.80
	Multivariate	Primary	-.43	.11	-.12	-3.83**
		Secondary	.10	.12	.03	.85
Number of previous cessation attempts	Univariate	Primary	.55	.27	.06	2.07*
	Univariate	Secondary	.39	.29	.04	1.34
	Multivariate	Primary	.53	.33	.05	1.59
		Secondary	.04	.37	.004	.12

* $p \leq .05$

** $p < .01$

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Table 8

Logistic regressions using the Primary Motives, Secondary Motives and Primary Motives to WISDM ratio to predict dichotomous variables

	Logistic Regression					
Dependent variable	**Analysis**	**Predictor**	**B**	**SE**	**Wald**	**OR**
Gender (men = 0)	Univariate	Primary	.08	.05	2.89	1.08
	Univariate	Secondary	.27	.05	27.76	1.31**
	Multivariate	Primary	-.11	.06	3.58	.90
		Secondary	.34	.06	28.38	1.41**
Household smoking restrictions (no = 0)	Univariate	Primary	-.29	.05	38.85	.75**
	Univariate	Secondary	-.16	.05	9.52	.86**
	Multivariate	Primary	-.32	.06	30.31	.72**
		Secondary	.06	.06	.82	1.06
Education (high school or less = 0)	Univariate	Primary	-.16	.05	11.17	.85**
	Univariate	Secondary	.05	.05	1.06	1.06
	Multivariate	Primary	-.30	.06	24.46	.74**
		Secondary	.25	.07	14.65	1.29**
Alcohol problems (no = 0)	Univariate	Primary	.29	.11	6.88	1.33**
	Univariate	Secondary	-.01	.12	.002	1.00
	Multivariate	Primary	.43	.13	10.84	1.54**
		Secondary	-.28	.14	3.93	.75*
Relapse at 1 week (no = 0)	Univariate	Primary	.21	.05	16.34	1.24**
	Univariate	Secondary	.15	.06	6.86	1.16**
	Multivariate	Primary	.20	.07	9.54	1.23**
		Secondary	.02	.07	.06	.80
Relapse at 6 months (no = 0)	Univariate	Primary	.21	.06	12.16	1.23**
	Univariate	Secondary	.10	.07	2.29	1.11
	Multivariate	Primary	.25	.08	10.31	1.28**
		Secondary	-.07	.09	.63	.94

* $p \leq .05$

** $p < .01$