



Full length article

Tobacco use and the interplay of internalizing, externalizing and substance use problems: A latent class analysis of data from the Population Assessment of Tobacco and Health Study

Ollie Ganz^{a,*}, Rajiv N. Rimal^{a,b}, Amanda L. Johnson^c, Amy M. Cohn^{c,d}, Kimberly Horn^e,
Cristine D. Delnevo^f, Andrea C. Villanti^{g,h}

^a Department of Prevention and Community Health, George Washington University Milken Institute School of Public Health, 950 New Hampshire Avenue NW, Washington, DC 20052, United States

^b Department of Health, Behavior and Society, Johns Hopkins Bloomberg School of Public Health, 615 N. Wolfe St., Baltimore, MD 21205, United States

^c Oklahoma Tobacco Research Center, University of Oklahoma Health Sciences Center, 655 Research Parkway, Oklahoma City, Oklahoma 73104, United States

^d Department of Oncology, Georgetown University Medical Center, 3800 Reservoir Rd. NW, Washington D.C. 20057, United States

^e Department of Population Health Sciences, Virginia Tech Carilion Research Institute, 2 Riverside Circle, Roanoke, VA 24016, United States

^f Center for Tobacco Studies, Rutgers School of Public Health, 683 Hoes Lane West, Piscataway, NJ 08854, United States

^g Vermont Center on Behavior and Health, University of Vermont, 1 South Prospect Street, Burlington, VT 05401, United States

^h Department of Psychiatry, University of Vermont, 1 South Prospect Street, Burlington, VT 05401, United States

ARTICLE INFO

Keywords:

Non-cigarette tobacco products
Mental health
Comorbidities
Substance use

ABSTRACT

Background: Cigarette smoking is disproportionately high among adults with two or more psychiatric disorders (psychiatric comorbidities), yet research on non-cigarette tobacco use among this population is scant. Additionally, most studies on tobacco use among this population rely on psychiatric diagnoses rather than individual symptoms, potentially excluding individuals with symptom-specific issues that increase their risk for tobacco use but do not meet the criteria for diagnosis. The objectives of this study were to identify unique classes of individuals based on symptoms of psychiatric disorders and to assess differences in demographic characteristics and tobacco use behaviors between classes.

Methods: This study used data from Wave 2 of the Population Assessment of Tobacco and Health Study adult dataset. Latent class analysis was used to classify individuals based on internalizing, externalizing and substance use problems. Bivariate and multivariable models examined the association between latent class membership and current use of cigarettes, cigar products, electronic nicotine delivery systems, pipe, hookah and smokeless tobacco products. Poly tobacco use was also examined.

Results: Three latent classes were identified. The “normative” class reported low prevalence of all symptoms, the “severe internalizing and non-violent externalizing” class reported severe internalizing problems and non-violent externalizing problems and the “severe” class reported high prevalence of all symptoms. Tobacco use was highest for the “severe” class and lowest for the “normative” class across products.

Conclusions: Individuals in the “severe” class may be at elevated risk of tobacco-related morbidity and mortality and would likely benefit from targeted tobacco control interventions.

1. Introduction

The prevalence of tobacco use among adults with psychiatric disorders is disproportionately high (Conway et al., 2017; Fu et al., 2014; Hagman et al., 2008; Hefner et al., 2019; Spears et al., 2019; Wang et al., 2018). A study using data from the Population Assessment of Tobacco and Health (PATH) Study (2013–2014) found that current tobacco use was associated with high internalizing, externalizing and

substance use problems for all tobacco products examined (Conway et al., 2017). For example, 20.1% of adults with severe internalizing problems reported any current tobacco use, compared to 9.2% of those with moderate or low internalizing problems. Internalizing problems refer to distress that is targeted inwards and include symptoms of psychiatric disorders such as anxiety and depression (Cosgrove et al., 2011); externalizing problems refer to distress that is targeted outwards and include symptoms of disorders such as conduct disorder and

* Corresponding author.

E-mail address: ganzo@gwmail.gwu.edu (O. Ganz).

<https://doi.org/10.1016/j.drugalcdep.2019.107686>

Received 31 May 2019; Received in revised form 4 October 2019; Accepted 14 October 2019

Available online 28 October 2019

0376-8716/ © 2019 Elsevier B.V. All rights reserved.

attention-deficit/hyperactivity disorder (ADHD) (Cosgrove et al., 2011).

Those with two or more psychiatric disorders (also known as having psychiatric comorbidities) are at an even greater risk for cigarette smoking compared to adults with one psychiatric disorder. Adults with psychiatric comorbidities smoke cigarettes at higher rates (Jané-Llopis et al., 2006; Lasser et al., 2000; Lawrence et al., 2009; McClave et al., 2010; Mykletun et al., 2008), are more nicotine dependent (Breslau et al., 2004; John et al., 2004; Magidson et al., 2012), are more likely to smoke daily (Breslau et al., 2004) and smoke more heavily (Lasser et al., 2000; McClave et al., 2010; Smith et al., 2014) compared to those with only one psychiatric disorder. While research on individuals with psychiatric comorbidities has been cigarette-centric, emerging research suggests that use of non-cigarette tobacco products may be higher among this population (King et al., 2018; Schauer et al., 2015). There is no research to date on the prevalence of poly tobacco use among individuals with psychiatric comorbidities, a behavior that is associated with nicotine dependence (Sung et al., 2018), poorer cessation outcomes (Hamari et al., 2013; Kasza et al., 2014; Tomar et al., 2010; Wetter et al., 2002) and may expose users to greater tobacco-related harms (Choi et al., 2017; Goniewicz et al., 2018), depending on the combination of products used, as well as the frequency and intensity of use. However, the increasing availability of different tobacco products (Pacek et al., 2019) and greater nicotine dependence among individuals with psychiatric comorbidities (Breslau et al., 2004; John et al., 2004; Magidson et al., 2012) suggests that this population may be susceptible to the concurrent use of two or more tobacco products.

Most studies on cigarette smoking among those with psychiatric comorbidities have looked at the association between number of psychiatric disorders and cigarette smoking (Lasser et al., 2000; Lawrence et al., 2009; McClave et al., 2010). These studies are valuable in that they demonstrate that psychiatric disorders cluster together to influence smoking behavior. They are limited, however, in that they do not provide insight into *how* psychiatric disorders cluster together. This is critical, since studies that have examined psychiatric comorbidities using advanced statistical techniques, such as finite mixture modeling, have found that psychiatric comorbidities manifest themselves in unique patterns among individuals (El-Gabalawy et al., 2013; Vaidyanathan et al., 2011; Vaughn et al., 2011; Weich et al., 2011). For example, one study identified five latent classes with unique groupings of psychiatric disorders, such as a class made up of adults with phobia diagnoses, panic disorder and depression (Vaidyanathan et al., 2011). These findings suggest that individuals with psychiatric comorbidities do not just differ on number or severity of psychiatric disorders; rather, psychiatric disorders cluster together to form distinct groups of people, with their own unique risk profiles (Vaidyanathan et al., 2011).

Another limitation of the current research on cigarette smoking among those with psychiatric comorbidities is that these studies only look at psychiatric diagnoses, such as presence of an anxiety disorder, as opposed to the individual symptoms that make up these disorders. There are limitations to diagnostic categorizations of psychiatric disorders (Brown and Barlow, 2009), which assume that psychiatric disorders exist at a particular cut point and don't take into account symptom-specific issues that may negatively impact individuals, even if they do not meet the criteria for diagnosis (Ameringer and Leventhal, 2013; Gintner, 2014; Kollins et al., 2005; Rojewski et al., 2016). One study of youth found that ADHD symptoms, even below the threshold required for clinical diagnosis, were significantly associated with smoking (Kollins et al., 2005). More research is needed to understand how symptoms of psychiatric disorders interact with each other to influence tobacco use behavior (Rojewski et al., 2016).

Using a large, nationally representative sample of US adults, the objectives of this study were to 1) use latent class analysis (LCA) to identify unique classes of individuals based on symptoms of psychiatric disorders, including internalizing, externalizing and substance use disorders, 2) assess differences in demographic characteristics between

classes and 3) examine differences in tobacco use behavior between latent classes. By identifying subgroups of individuals based on the intersection of symptoms of psychiatric disorders, these findings may provide evidence for how tobacco control interventions can target the most high-risk individuals to achieve the best health outcomes (Lanza and Rhoades, 2013).

2. Methods

2.1. Data source and sample size

The PATH Study is a nationally representative, longitudinal cohort study designed to assess tobacco-related risk factors and behaviors among non-institutionalized individuals in the United States (U.S.) who are ages 12 and over (Hyland et al., 2016). Data from Wave 2 of the adult public use files (PUF) were utilized for this study, which includes adults ages 18 and over ($n = 28,362$) (Hyland et al., 2016; Inter-university Consortium for Political and Social Research and Westat, 2018). A total of 17 respondents had missing data for all LCA indicators and were dropped from the analytic sample, resulting in a final sample size of 28,345 respondents.

2.2. Sampling frame and data collection

For Wave 1, PATH used a four-stage stratified area probability sample design, with a two-phase design for the adult cohort toward the end of data collection (Hyland et al., 2016). The study oversampled for young adults (aged 18–24), African Americans and tobacco users (Hyland et al., 2016; Inter-university Consortium for Political and Social Research and Westat, 2018). There was no additional sampling done for Wave 2. All Wave 1 respondents were eligible for Wave 2 as long as they continued to live in the U.S. and weren't incarcerated (Inter-university Consortium for Political and Social Research and Westat, 2018). More details on the PATH study design can be found elsewhere (Hyland et al., 2016; Inter-university Consortium for Political and Social Research and Westat, 2018). Wave 2 data collection occurred from 2014 to 2015 (Inter-university Consortium for Political and Social Research and Westat, 2018).

2.3. Measures

2.3.1. Internalizing, externalizing and substance use problems

A modified version of the Global Appraisal of Individual Needs–Short Screener (GAIN-SS) was used to measure internalizing (Internalizing Disorder Screener (IDScr)), externalizing (Externalizing Disorder Screener (EDScr)) and substance use problems (Substance Disorder Screener (SDScr)). For each screener, participants reported the number of symptoms they had experienced in the past year. Answer choices for all scales included “past month,” “2–12 months ago,” “over a year ago” and “never.” All GAIN-SS items were dichotomized, such that those who answered “past month” or “2–12 months ago” for a given item were categorized as having a given symptom in the past year. See Table 2 for specific items included in the PATH Study from the GAIN-SS. Only respondents who reported ever using alcohol or ever using drugs were asked the SDScr questions. Those who did not report ever using alcohol or drugs were coded as “never” for all SDScr items ($n = 2,268$). The GAIN-SS does not provide a clinical diagnosis of a psychiatric disorder.

2.3.2. Tobacco use

Respondents were asked about use of cigarettes, traditional cigars, cigarillos, filtered cigars, electronic nicotine delivery systems (ENDS), hookah, pipe, smokeless tobacco (e.g. loose snus, moist snuff, dip, spit, or chewing tobacco), snus and dissolvable tobacco. Use of traditional cigars, cigarillos and filtered cigars were combined into an “any cigar use” variable and smokeless tobacco, snus and dissolvable tobacco were

Table 1

Model Fit Indices and Odds of Correct Classification for 2–6 Solutions of Internalizing, Externalizing and Substance Use Problems (n = 28,345).
Data source: Adult Population Assessment of Tobacco and Health Public Use File, Wave 2.

Model fit									
Classes	Number of free parameters	LL	AIC	BIC	Sample size adjusted BIC	VLMR LRT	LMR	BLRT	Entropy
1	18	–221565.10	443166.23	443314.77	443257.56	n/a	n/a	n/a	n/a
2	37	–186479.80	373033.62	373338.95	373221.37	–221565.11	69812.21	–221565.11***	0.869
3	56	–178799.66	357711.32	358173.44	357995.48	–186479.81***	15281.85***	–186479.81***	0.877
4	75	–175674.20	351498.34	352117.26	351878.91	–178799.66***	6219.05***	–178799.66***	0.834
5	94	–173258.50	346705.09	347480.80	347182.07	–175674.17***	4806.57***	–175674.17***	0.838
6	113	–171041.20	342308.46	343240.96	342881.85	–173258.55***	4411.99***	–173258.55***	0.834

Odds of Correct Classification ^a						
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
1	∞					
2	19.83	30.25				
3	31.26	12.16	7.77			
4	6.75	22.81	8.61	6.19		
5	3.67	4.75	9.31	32.33	8.90	
6	26.03	3.63	4.81	4.18	9.00	9.42

*p < .05; **p < .01; ***p < .001.

LL = log likelihood; AIC = Akaike information criterion; BIC = Bayesian information criterion; VLMR = Vuong-Lo-Mendell-Rubin; LRT = likelihood ratio test; LMR = Lo-Mendell-Rubin; BLRT = bootstrap likelihood ratio test.

Note: The best fit solution is indicated in bold.

∞ = perfect classification.

^a Odds of correct classification of 5 or greater suggests sufficient latent class separation (Collins and Lanza, 2010).

combined into an “any smokeless tobacco use” variable due to sample size limitations. Cigarette users were defined as individuals who smoked at least 100 cigarettes in their lifetime and currently smoked “some days” or “every day” (Kasza et al., 2017). Users of all other tobacco products were defined as individuals who had ever used the product “fairly regularly” and currently used that product “some days” or “every day” (Kasza et al., 2017).

Based on these definitions of product use, three poly tobacco use variables were created. Any poly tobacco use was defined as use of at least two of the following products: cigarettes, ENDS, traditional cigars, cigarillos, filtered cigars, pipe, hookah, smokeless tobacco snus and dissolvable tobacco. Any combustible poly tobacco use was defined as use of at least two of the following products: cigarettes, traditional cigars, cigarillos, filtered cigars, pipe and hookah. Combustible and noncombustible poly tobacco use was defined as use of at least one of combustible product (cigarettes, traditional cigars, cigarillos, filtered cigars, pipe or hookah) AND at least one noncombustible product (END, smokeless tobacco snus and dissolvable tobacco).

2.3.3. Demographic characteristics

Demographic characteristics included age, gender, race/ethnicity, highest level of education completed, household annual income and sexual orientation.

2.4. Data analysis

LCA is a statistical analysis technique in which distinct subgroups of individuals are identified based on an underlying, latent construct (Collins and Lanza, 2010; Methodology Center, Penn State College of Health and Human Development, 2018), which is defined based on the complex interrelationship between multiple risk factors. The 18 GAIN-SS items were included as indicators for the LCA. A series of iterative models with an increasing number of classes was estimated, ranging from one to six classes. The correct model was selected based on model fit indices, odds of correct classification (OCC) and interpretability. The following model fit criteria were used in this study: the log likelihood (LL), the Akaike information criterion (AIC), the Bayesian information criterion (BIC), the sample size adjusted BIC, entropy, the Lo-Mendell-Rubin (LMR) test, Vuong-Lo-Mendell-Rubin adjusted likelihood ratio test (VLMR-LRT) and the bootstrap likelihood ratio test (BLRT) (Collins

and Lanza, 2010; Nylund-Gibson and Choi, 2018; Nylund et al., 2007). Lower LL, AIC, BIC and sample size adjusted BIC indicate better model fit (Nylund-Gibson and Choi, 2018). Entropy values range from 0 to 1, with higher values indicating greater latent class separation (Asparouhov and Muthén, 2018) (a value of > .80 is considered acceptable (Nylund-Gibson and Choi, 2018; Smack et al., 2017)). LMR, VLMR-LRT and BLRT tests all provide p-values that allow for a comparison of model fit between a model with k classes compared to k-1 classes (i.e. comparison of 4- and 3-class models) (Nylund-Gibson and Choi, 2018; Nylund et al., 2007). An OCC of 5 or greater suggests sufficient latent class separation (Nagin, 2005). Missing data were addressed using full-information maximum likelihood (FIML) (Collins and Lanza, 2010). The LCA was conducted using Mplus Version 8.1 (Muthen and Muthen, 2018).

After the best fitting model was selected, class membership data were exported from Mplus and merged with the Wave 2 adult PATH dataset in Stata/SE 15.1 (StataCorp LP, 2017). Data in Stata were weighted to be nationally representative and to adjust for non-response and over sampling. Variance estimation procedures were used to account for stratification and clustering utilized in sampling. Replicate weights that were calculated using Fay’s variant of balanced repeated replication (BRR) were used to calculate standard errors (Hyland et al., 2016; Inter-university Consortium for Political and Social Research and Westat, 2018).

Weighted chi-square tests were used to estimate the proportion of respondents in each latent class and in the overall sample who reported past-year symptoms of internalizing, externalizing and substance use problems. Weighted chi-square tests were also used to examine demographic characteristics and tobacco-use behavior in each latent class and in the overall sample.

Separate multivariable logistic regression models were used to examine the association between latent class membership and current use of cigarettes, any cigar product, ENDS, pipe, hookah, any smokeless tobacco product and each type of poly tobacco use, controlling for sociodemographic characteristics. The multivariable model for hookah use was restricted to young adults (ages 18–34), since almost all current hookah users were in this age group (92.48%).

Table 2
Weighted prevalence of internalizing, externalizing and substance use problems in the 3-class model.
Data source: Adult Population Assessment of Tobacco and Health Public Use File, Wave 2.

	Total (n = 28,345)	Class 1 Normative (n = 16,036)	Class 2 High internalizing and non-violent externalizing (n = 9,874)	Class 3 Severe (n = 2,435)	P-value ^a
Past year externalizing problems					
Lied or conned to get things you wanted or to avoid having to do something	14.78%	4.05%	30.29%	54.32%	< .001
Had a hard time paying attention at school, work, or home	26.80%	4.63%	65.50%	68.87%	< .001
Had a hard time listening to instructions at school, work, or home	20.06%	1.73%	51.36%	59.06%	< .001
Were a bully or threatened other people	3.47%	0.68%	6.17%	21.59%	< .001
Started physical fights with other people	1.82%	0.31%	2.56%	15.80%	< .001
Felt restless or the need to run around or climb on things	11.01%	2.51%	23.49%	41.14%	< .001
Gave answers before the other person finished asking the question	44.02%	29.42%	68.98%	74.57%	< .001
Past year internalizing problems					
Felt very trapped, lonely, sad, blue, depressed, or hopeless about the future	25.90%	5.25%	60.52%	74.12%	< .001
Sleep trouble, such as bad dreams, sleeping restlessly, or falling asleep during the day	40.86%	19.19%	78.80%	81.42%	< .001
Felt very anxious/nervous/tense/scared/panicked/like something bad was going to happen	29.62%	5.94%	70.91%	75.01%	< .001
Became very distressed and upset when something reminded you of the past	24.27%	3.94%	58.31%	71.58%	< .001
Past year substance use problems^b					
Used alcohol or other drugs weekly or more often	35.07%	28.37%	38.64%	94.52%	< .001
Spent a lot of time getting alcohol or other drugs	11.26%	6.49%	9.95%	75.99%	< .001
Spent a lot of time using or recovering from alcohol or other drugs	4.37%	0.92%	1.65%	61.76%	< .001
Alcohol /other drugs caused social problems/leading to fights/getting you into trouble	3.50%	0.66%	0.44%	55.41%	< .001
Reduced your involvement with activities (work/school/home/social events)	3.42%	0.01%	0.01%	52.19%	< .001
Had withdrawal problems (shaky hands/throwing up/having trouble sitting still or sleeping)	3.72%	0.01%	2.75%	47.24%	< .001
Use of alcohol/ other drugs to stop being sick or avoid withdrawal problems	2.33%	0.21%	0.51%	38.30%	< .001
Class size (unweighted n)	-	16,036	9,874	2,435	-
Class size (unweighted %)	-	56.57%	34.84%	8.59%	-

Items obtained from a modified version of the Global Appraisal of Individual Needs– Short Screeners (Internalizing Disorder Screener, Externalizing Disorder Screener and Substance Disorder Screener.

Note: Frequencies are unweighted.

^a P-values obtained from chi-square tests.

^b Only respondents who reported ever using alcohol or ever using drugs were asked the Substance Disorder Screener questions. Those who did not report ever using alcohol or drugs were coded as “never” for all Substance Disorder Screener items (n = 2,268).

3. Results

Table 1 presents the fit statistics for the latent class models. The three-class solution was chosen as the best model. The three- through six-class models all had statistically significant VLMR LRT and Lo-Mendell-Rubin Adjusted LRT test statistics, as well as entropy values greater than .80. However, the five- and six-class models both had poor latent class separation and were therefore not considered for the final model ($OCC < 5$). AIC, BIC and sample size-adjusted BIC supported the four-class model. However, after inspection of interpretability, there was conceptual overlap among the four-classes and therefore the three-class model was selected. Chi-square tests for missing completely at random (MCAR) were all not statistically significant ($p > .05$), meaning that the probability of a respondent having missing data was not related to any variables in the study (Collins and Lanza, 2010).

Weighted responses to internalizing, externalizing and substance use measures by latent class and prevalence of each class in the sample can be found in Table 2. The three latent classes are described as “normative” (Class 1; 56.57%), “high internalizing and non-violent externalizing” (Class 2; 34.84%) and “severe” (Class 3; 8.59%). Class names were informed by a study by Vaughn et al (Vaughn et al., 2011) (note that these classifications are based on symptoms of psychiatric disorders and do not necessarily mean that individuals met criteria for diagnosis of a disorder).

The “normative” class was characterized by low prevalence of symptoms. Endorsement of externalizing problems (range of 0.31%–29.42%) and internalizing problems (range of 3.94%–19.19%) was low for the “normative” class. A total of 28.37% and 6.49% of the “normative” class reported having “used alcohol or other drugs weekly or more often” in the past year and reported having “spent a lot of time getting alcohol or drugs,” respectively. The remainder of the substance use statements, which suggest more severe substance use problems, were endorsed by almost no one in the “normative” class ($< 1\%$).

Over half of the “high internalizing and non-violent externalizing” class endorsed “hard time paying attention” (65.50%), “hard time listening” (51.36%) and “gave answers before question was finished” (68.98%) among the externalizing items. However, fewer individuals in this class reported that they had “lied/conned to get something” (30.29%), “bullied/threatened people” (6.17%) or “started a physical fight” (2.56%). A large proportion of respondents in this class reported internalizing symptoms (range of 58.31%–78.80%). A total of 38.64% of the “high internalizing and non-violent externalizing” class reported having “used alcohol or other drugs weekly or more often” in the past year. Only 9.95% of this class reported having “spent a lot of time getting alcohol or drugs” in the past year and endorsement of the remaining substance use items was low ($< 3\%$).

The “severe” class was characterized by high prevalence of all symptoms. Similar to the “high internalizing and non-violent externalizing class,” a large proportion of the “severe” classes endorsed “hard time paying attention” (68.87%), “hard time listening” (59.06%) and “gave answers before question was finished” (74.57%). Compared to the “high internalizing and non-violent externalizing” class, however, a greater proportion of the “severe” class endorsed “lied/conned to get something,” (30.29% vs. 54.32%) “bullied/threatened people” (6.17% vs. 21.59%) and “started a physical fight” (2.56% vs. 15.80%). Internalizing symptoms were highly prevalent in the “severe” classes (range of 71.58%–81.42%). Nearly everyone in the “severe” class reported having “used alcohol or other drugs weekly or more often” in the past year (94.52%). Over half of respondents indicated having “spent a lot of time using or recovering,” “alcohol or drugs causing social problems, fights, or trouble with others” and “reduced involvement with activities at work, school, home or social events” in the past year. Nearly half reported “withdrawal problems” in the past year (47.24%) and 38.30% reported “use of alcohol or other drugs to stop being sick or avoid withdrawal problems.”

Table 3 presents the weighted, bivariate demographic and tobacco-

related correlates of latent class membership. There were differences by latent class for all variables examined ($p < .001$). The “normative” class was older compared to the “severe” class, for which half of respondents were under the age of 35 (24.07% were ages 18–24 and 26.27% were ages 25–34). The “high internalizing and non-violent externalizing” class was approximately evenly distributed across age groups. Compared to the other two classes, a greater proportion of members of the “severe” class were male (59.53%), non-Hispanic, Black (13.05%), Hispanic (19.50%), had lower levels of education (approximately 43% with a high school degree or less), lower levels of income (about 60% with annual household income of less than \$50,000) and identify as lesbian, gay, bisexual or something else (10.59%). The distribution of race/ethnicity, educational attainment, household annual income and sexual orientation was similar for the “normative” and “high internalizing and non-violent externalizing” classes. Cigarette and ENDS use were highest for those in the “severe” class (45.62% and 10.20%), followed by the “high internalizing and non-violent externalizing” class (20.71% and 4.52%) and then the “normative” class (15.39% and 2.45%). Use of cigars, pipe, hookah and smokeless tobacco was highest among the “severe” class compared to the other two classes, for whom use of these products was similar. The “severe” class reported higher prevalence of any poly tobacco use (17.77%), combustible poly tobacco (9.49%) and combustible and noncombustible poly tobacco use (11.35%) compared to the other two classes.

Table 4 reports findings from the multivariable models looking at single tobacco product use. Odds of current product use were significantly higher for the “high internalizing and non-violent externalizing” and “severe” classes compared to the “normative” class for cigarettes, ENDS, cigars, pipe and hookah. For smokeless tobacco, the “high internalizing and non-violent externalizing” class reported lower odds of current, established use (odds ratio (OR): 0.74, 95% confidence interval (CI): 0.62, 0.88) and the “severe” class reported higher odds of current, established use (OR: 1.79, 95% CI: 1.46, 2.21) compared to the “normative” class.

Table 5 reports findings from the multivariable models looking at poly tobacco product use. Odds of use were significantly higher for the “high internalizing and non-violent externalizing” and “severe” classes compared to the “normative” class for all three types of poly tobacco use.

4. Discussion

Using a large, nationally representative sample, this study identified three latent classes of adults based on symptoms of internalizing, externalizing and substance use problems, which differed in terms of tobacco use behavior. The “severe” class had a high prevalence of symptoms of internalizing, externalizing and substance use problems and had the highest prevalence of tobacco use across all products. The “high internalizing and non-violent externalizing” class was characterized by high prevalence of symptoms of internalizing problems and non-violent externalizing problems and reported lower prevalence of tobacco use compared to the “severe” class. Although about half of this class reported using alcohol or drugs weekly, prevalence of problematic drug and alcohol use behavior was low. Lastly, the “normative” class reported low symptoms of all three disorders. The “normative” class reported lower prevalence of tobacco use compared to the “severe” group for all products and similar or lower prevalence of tobacco use compared to the “high internalizing and non-violent externalizing” class. The characteristics of the three latent classes in this paper align with other studies that have examined the interplay of psychiatric disorders. These studies all identified one group with low prevalence of any psychiatric disorder and at least two other groups characterized by psychiatric comorbidities (Lawrence et al., 2009; Vaidyanathan et al., 2011; Vaughn et al., 2011; Weich et al., 2011).

Examination of tobacco use behavior indicates that the “severe” class is the highest risk group and that the “normative” class is the

Table 3
Weighted Latent Class Demographic and Tobacco Use Characteristics.
Data source: Adult Population Assessment of Tobacco and Health Public Use File, Wave 2.

	Total (n = 28,345)	Class 1 Normative (n = 16,036)	Class 2 High internalizing and non-violent externalizing (n = 9,874)	Class 3 Severe (n = 2,435)	P-value ^a
Age					< .001
18-24	12.69%	9.79%	16.75%	24.07%	
25-34	17.48%	15.75%	19.57%	26.27%	
35-44	16.46%	16.36%	16.38%	18.09%	
45-54	17.23%	16.56%	18.60%	17.53%	
55-64	17.01%	18.40%	15.38%	9.60%	
65 +	19.13%	23.14%	13.32%	4.45%	
Gender					< .001
Male	47.96%	50.12%	41.49%	59.53%	
Female	52.04%	49.88%	58.51%	40.47%	
Race/ethnicity					< .001
Non-Hispanic, White	65.76%	64.43%	69.32%	61.06%	
Non-Hispanic, Black	11.22%	11.68%	9.96%	13.05%	
Non-Hispanic, Other	7.66%	8.21%	6.72%	6.39%	
Hispanic	15.36%	15.68%	14.00%	19.50%	
Education					< .001
Less than high school	11.30%	11.64%	10.10%	14.17%	
GED	5.21%	4.88%	5.44%	7.93%	
High school graduate	22.97%	23.90%	21.30%	21.40%	
Some college or Associates degree	32.04%	29.85%	35.78%	36.61%	
Bachelor's degree	18.06%	18.39%	17.88%	15.15%	
Advanced degree	10.42%	11.34%	9.49%	4.74%	
Household Income					< .001
Less than \$10,000	12.58%	11.31%	13.41%	22.35%	
\$10,000 to \$24,999	19.84%	18.54%	21.55%	24.88%	
\$25,000 to \$49,999	22.81%	23.07%	22.62%	21.01%	
\$50,000 to \$99,999	26.08%	27.15%	25.30%	18.35%	
\$100,000 or more	18.68%	19.92%	17.12%	13.41%	
Sexual Orientation					< .001
Lesbian, gay, bisexual, something else	4.84%	3.22%	7.18%	10.59%	
Straight	95.16%	96.78%	92.82%	89.41%	
Tobacco Use					
Current cigarette use	18.62%	15.39%	20.71%	45.62%	< .001
Current ENDS use	3.50%	2.45%	4.52%	10.20%	< .001
Current cigar use (any type) ^b	2.79%	2.20%	2.83%	9.99%	< .001
Current pipe use	0.44%	0.33%	0.52%	1.32%	< .001
Current hookah use	1.10%	0.69%	1.36%	4.54%	< .001
Current smokeless tobacco use (any type) ^c	2.72%	2.74%	2.03%	6.54%	< .001
Any poly tobacco use ^d	4.98%	3.55%	5.76%	17.77%	< .001
Combustible poly tobacco use ^e	2.31%	1.58%	2.58%	9.49%	< .001
Combustible and noncombustible poly tobacco use ^f	3.16%	2.21%	3.72%	11.35%	< .001

GED = General Education Development; ENDS = electronic nicotine delivery systems.

Note: Frequencies are unweighted.

^a P-values obtained from chi-square tests.

^b Includes traditional cigars, cigarillos and filtered cigars.

^c Includes smokeless tobacco, snus and dissolvable tobacco.

^d Defined as current use of at least two of the following products: cigarettes, ENDS, traditional cigars, cigarillos, filtered cigars, pipe, hookah, smokeless tobacco snus and dissolvable tobacco.

^e Defined as current use of at least two of the following products: cigarettes, traditional cigars, cigarillos, filtered cigars, pipe and hookah.

^f Defined as current use of at least one of the following products: cigarettes, traditional cigars, cigarillos, filtered cigars, pipe and hookah AND at least one of the following: ENDS, smokeless tobacco snus and dissolvable tobacco.

lowest risk group. Specifically, for cigarettes, cigars, ENDS, pipe and hookah, prevalence of use was lowest for the “normative” class and highest for the “severe” class. Findings from the multivariable models were similar, showing that for all products (except smokeless tobacco), odds of use were greater for those in the “high internalizing and non-violent externalizing” and “severe” classes compared to the “normative” class. Other studies have also found that cigarette use is most prevalent among individuals with psychiatric comorbidities (Jané-Llopis et al., 2006; Lasser et al., 2000; Lawrence et al., 2009; McClave et al., 2010; Mykletun et al., 2008). However, this is one of the first studies to identify high prevalence of non-cigarette tobacco product use and poly tobacco use among this population. Combustible tobacco products (e.g. cigars, hookah and pipe) are the most harmful tobacco products (U.S. Department of Health and Human Services, 2014) and

therefore disproportionate use of these products singularly or together (poly tobacco use) raise concern that those with psychiatric comorbidities, in particular those in the “severe” class, are at an elevated risk for tobacco-related morbidity and mortality, even compared to those with a single psychiatric disorder, who already suffer greatly from tobacco-related disease (Callaghan et al., 2014; Campion et al., 2008; Schroeder and Morris, 2010; Tam et al., 2016).

Disproportionate ENDS use and combustible and noncombustible poly tobacco use among the “severe” class, followed by the “high internalizing and non-violent externalizing” class, suggests that ENDS products may be appealing to individuals with psychiatric comorbidities. Although this is the first study to report on ENDS use among adults with psychiatric comorbidities, research shows that serious psychological distress is associated with e-cigarette¹ use (Bianco, 2018; Park

Table 4
Weighted multivariable logistic regression models of tobacco use by latent class (n = 28,345).
Data source: Adult Population Assessment of Tobacco and Health Public Use File, Wave 2.

Latent class	Current cigarette use	Current ENDS use	Current cigar use ^a	Current pipe use	Current hookah use ^b	Current smokeless tobacco use ^c
Class 1	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Class 2	Reference	Reference	Reference	Reference	Reference	Reference
Class 3	1.23 (1.14, 1.33)***	1.49 (1.30, 1.69)***	1.26 (1.07, 1.48)**	1.58 (1.12, 2.25)*	1.35 (1.08, 1.67)**	0.74 (0.62, 0.88)**
Age	3.37 (2.90, 3.93)***	2.62 (2.20, 3.11)***	3.35 (2.74, 4.08)***	2.59 (1.59, 3.24)***	2.87 (2.13, 3.87)***	1.79 (1.46, 2.21)***
18-24	Reference	Reference	Reference	Reference	Reference	Reference
25-34	2.07 (1.85, 2.31)***	1.09 (0.95, 1.26)	0.96 (0.81, 1.13)	0.93 (0.62, 1.40)	0.35 (0.27, 0.44)***	0.97 (0.80, 1.19)
35-44	2.08 (1.84, 2.34)***	0.88 (0.73, 1.06)	0.74 (0.60, 0.92)**	0.76 (0.44, 1.34)	-	0.97 (0.77, 1.24)
45-54	1.67 (1.50, 1.86)***	0.53 (0.43, 0.65)***	0.79 (0.65, 0.97)*	0.72 (0.35, 1.48)	-	0.77 (0.60, 0.99)*
55-64	1.33 (1.16, 1.52)***	0.41 (0.33, 0.52)***	0.70 (0.56, 0.87)**	0.76 (0.42, 1.36)	-	0.34 (0.26, 0.46)***
65+	0.44 (0.38, 0.51)***	0.16 (0.11, 0.24)***	0.43 (0.31, 0.60)***	0.67 (0.37, 1.22)	-	0.30 (0.23, 0.38)***
Gender	Reference	Reference	Reference	Reference	Reference	Reference
Male	0.72 (0.67, 0.77)***	0.76 (0.67, 0.85)***	0.25 (0.21, 0.29)***	0.06 (0.03, 0.11)***	0.63 (0.52, 0.76)**	0.05 (0.04, 0.06)***
Female	Reference	Reference	Reference	Reference	Reference	Reference
Race/ethnicity	Reference	Reference	Reference	Reference	Reference	Reference
Non-Hispanic, White	0.67 (0.60, 0.75)***	0.37 (0.31, 0.45)***	1.54 (1.30, 1.82)***	0.28 (0.14, 0.59)**	1.09 (0.73, 1.62)	0.14 (0.10, 0.20)***
Non-Hispanic, Black	0.67 (0.58, 0.77)***	0.83 (0.67, 1.02)	0.55 (0.42, 0.73)***	0.70 (0.40, 1.21)	1.85 (1.34, 2.56)***	0.39 (0.30, 0.51)***
Non-Hispanic, Other	0.33 (0.29, 0.37)***	0.36 (0.29, 0.44)	0.56 (0.45, 0.68)***	0.31 (0.18, 0.53)***	1.25 (0.97, 1.62)	0.11 (0.08, 0.15)***
Hispanic	Reference	Reference	Reference	Reference	Reference	Reference
Education	Reference	Reference	Reference	Reference	Reference	Reference
Less than high school	1.42 (1.16, 1.73)**	1.51 (1.14, 2.00)**	1.09 (0.81, 1.47)	1.03 (0.49, 2.14)	1.93 (1.18, 3.16)**	0.88 (0.66, 1.18)
GED	0.72 (0.64, 0.82)***	0.96 (0.76, 1.20)	0.83 (0.65, 1.06)	0.99 (0.52, 1.90)	1.32 (0.89, 1.94)	0.90 (0.69, 1.17)
High school graduate	0.57 (0.50, 0.64)***	1.04 (0.83, 1.31)	0.96 (0.76, 1.21)	1.31 (0.74, 2.31)	1.76 (1.19, 2.60)**	0.67 (0.54, 0.82)***
Some college or Associates degree	0.26 (0.22, 0.30)***	0.40 (0.30, 0.54)***	0.75 (0.54, 1.05)	1.48 (0.78, 2.79)	1.57 (1.01, 2.44)*	0.29 (0.21, 0.40)
Bachelor's degree	0.17 (0.14, 0.21)***	0.31 (0.21, 0.46)***	0.60 (0.39, 0.92)*	1.97 (0.92, 4.23)	0.91 (0.42, 1.97)	0.20 (0.13, 0.31)***
Advanced degree	Reference	Reference	Reference	Reference	Reference	Reference
Household Income	Reference	Reference	Reference	Reference	Reference	Reference
Less than \$10,000	0.80 (0.71, 0.90)***	0.90 (0.73, 1.11)	0.59 (0.49, 0.71)***	0.70 (0.42, 1.16)	0.77 (0.59, 1.01)	0.98 (0.75, 1.30)
\$10,000 to \$24,999	0.58 (0.51, 0.67)***	0.81 (0.67, 0.97)*	0.42 (0.34, 0.53)***	0.46 (0.26, 0.82)**	0.69 (0.52, 0.92)*	1.12 (0.87, 1.44)
\$25,000 to \$49,999	0.40 (0.34, 0.46)***	0.71 (0.57, 0.88)**	0.40 (0.32, 0.50)***	0.30 (0.17, 0.54)	0.73 (0.55, 0.98)*	1.13 (0.87, 1.47)
\$50,000 to \$99,999	0.24 (0.20, 0.28)***	0.55 (0.43, 0.72)***	0.45 (0.35, 0.57)***	0.14 (0.07, 0.29)	0.92 (0.63, 1.34)	0.93 (0.64, 1.36)
\$100,000 or more	Reference	Reference	Reference	Reference	Reference	Reference
Sexual Orientation	1.27 (1.08, 1.48)**	1.67 (1.33, 2.09)***	1.56 (1.20, 2.02)***	2.20 (0.99, 4.80)	1.67 (1.23, 2.27)**	0.39 (0.22, 0.69)**
Lesbian, gay, bisexual, something else	Reference	Reference	Reference	Reference	Reference	Reference
Straight	Reference	Reference	Reference	Reference	Reference	Reference

GED = General Education Development; ENDS = electronic nicotine delivery systems; AOR = adjusted odds ratio; CI = confidence interval.

* p < .05.

** p < .01.

*** p < .001.

^a Includes traditional cigars, cigarillos and filtered cigars.

^b Analysis restricted to young adults, ages 18-34 (n = 13,844).

^c Includes smokeless tobacco, snus and dissolvable tobacco.

Table 5

Weighted multivariable logistic regression models of poly tobacco use by latent class (n = 28,345).

Data source: Adult Population Assessment of Tobacco and Health Public Use File, Wave 2.

	Any poly tobacco use ^a	Combustible poly tobacco use ^b	Combustible and noncombustible poly tobacco use ^c
Latent class	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Class 1	Reference	Reference	Reference
Class 2	1.42 (1.26, 1.57)***	1.41 (1.21, 1.64)***	1.39 (1.22, 1.59)***
Class 3	3.51 (3.03, 4.08)***	3.67 (2.98, 4.50)***	3.27 (2.78, 3.86)***
Age			
18-24	Reference	Reference	Reference
25-34	1.04 (0.91, 1.20)	0.88 (0.72, 1.07)	1.08 (0.93, 1.26)
35-44	0.85 (0.73, 0.98)*	0.58 (0.46, 0.74)***	0.96 (0.80, 1.15)
45-54	0.56 (0.48, 0.65)***	0.57 (0.46, 0.71)***	0.50 (0.40, 0.62)***
55-64	0.42 (0.35, 0.50)***	0.52 (0.41, 0.66)***	0.29 (0.23, 0.38)***
65+	0.16 (0.12, 0.20)***	0.19 (0.13, 0.27)***	
Gender			
Male	Reference	Reference	Reference
Female	0.39 (0.35, 0.43)***	0.29 (0.25, 0.35)***	0.50 (0.43, 0.57)***
Race/ethnicity			
Non-Hispanic, White	Reference	Reference	Reference
Non-Hispanic, Black	0.53 (0.45, 0.62)***	1.00 (0.83, 1.20)	0.29 (0.23, 0.36)***
Non-Hispanic, Other	0.69 (0.57, 0.85)***	0.84 (0.63, 1.11)	0.67 (0.53, 0.85)**
Hispanic	0.30 (0.25, 0.35)***	0.47 (0.38, 0.57)***	0.24 (0.19, 0.30)***
Education			
Less than high school	Reference	Reference	Reference
GED	1.32 (1.03, 1.68)*	1.16 (0.83, 1.63)	1.48 (1.09, 2.00)*
High school graduate	0.87 (0.73, 1.04)	0.78 (0.61, 1.00)	0.93 (0.75, 1.15)
Some college or Associates degree	0.89 (0.76, 1.06)	0.86 (0.70, 1.07)	0.95 (0.78, 1.16)
Bachelor's degree	0.40 (0.31, 0.50)***	0.51 (0.37, 0.69)***	0.37 (0.27, 0.49)***
Advanced degree	0.33 (0.24, 0.46)***	0.42 (0.26, 0.68)**	0.30 (0.21, 0.43)***
Household Income			
Less than \$10,000	Reference	Reference	Reference
\$10,000 to \$24,999	0.70 (0.60, 0.83)***	0.66 (0.53, 0.80)***	0.82 (0.66, 1.03)
\$25,000 to \$49,999	0.53 (0.45, 0.62)***	0.42 (0.34, 0.54)***	0.66 (0.54, 0.80)***
\$50,000 to \$99,999	0.44 (0.37, 0.52)***	0.34 (0.26, 0.43)***	0.58 (0.46, 0.72)***
\$100,000 or more	0.34 (0.28, 0.42)***	0.25 (0.18, 0.35)***	0.41 (0.32, 0.53)***
Sexual Orientation			
Lesbian, gay, bisexual, something else	0.66 (0.55, 0.79)***	0.54 (0.42, 0.70)***	0.67 (0.54, 0.83)***
Straight	Reference	Reference	Reference

GED = General Education Development; AOR = adjusted odds ratio; CI = confidence interval.

* p < .05.

** p < .01.

*** p < .001.

^a Defined as current use of at least two of the following products: cigarettes, ENDS, traditional cigars, cigarillos, filtered cigars, pipe, hookah, smokeless tobacco snus and dissolvable tobacco.^b Defined as current use of at least two of the following products: cigarettes, traditional cigars, cigarillos, filtered cigars, pipe and hookah.^c Defined as current use of at least one of the following products: cigarettes, traditional cigars, cigarillos, filtered cigars, pipe and hookah AND at least one of the following: ENDS, smokeless tobacco snus and dissolvable tobacco.

et al., 2017). ENDS may be appealing to adults with psychiatric comorbidities for several reasons; they may be using these products as a potential harm reduction tool or smoking cessation device (Pacek et al., 2019), as a means of social connectedness to other ENDS users or as a means of obtaining nicotine more discreetly, as more places are restricting cigarette smoking (Debell et al., 2014; Park et al., 2017). However, these questions are not addressed in this study and more research is needed to understand reasons for ENDS use among those with psychiatric comorbidities.

Although the “high internalizing and non-violent externalizing” and “severe” classes in this study were both characterized by psychiatric comorbidities, the high proportion of violent behavior and substance use problems in the “severe” class distinguishes the two classes from one another. High substance use problems may be a driving factor in higher tobacco use among this class, as other studies have found substance use to be more strongly associated with tobacco use compared to other psychiatric disorders (Lawrence et al., 2009; Smith et al., 2014; Talati et al., 2016). These groups also differed in terms of demographic characteristics. For example, individuals in the “high internalizing and

non-violent externalizing” class were more likely to be older, female and non-Hispanic, White compared to the “severe” class. These differences demonstrate that individuals with psychiatric comorbidities vary depending on the specific combination of psychiatric disorders that they have. A study by McLean et al. found that women with an anxiety disorder were more likely to be diagnosed with major depressive disorder and bulimia nervosa, while men with an anxiety disorder were more likely to be diagnosed with a SUD, ADHD and intermittent explosive disorder (McLean et al., 2011). Other studies have also identified demographic correlates of psychiatric comorbidities, which are distinct based on the disorders assessed (Jané-Llopis et al., 2006; Magidson et al., 2012; Mykletun et al., 2008; Smith et al., 2014; Substance Abuse and Mental Health Services Administration, 2018; Williams and Ziedonis, 2004). Taken together with our study findings, these studies demonstrate that individuals with psychiatric comorbidities are a heterogeneous group (Vaidyanathan et al., 2011).

The “severe” class, characterized by symptoms of internalizing, externalizing and substance use disorders, demonstrated the highest risk for tobacco use across all products, as well as poly tobacco use and therefore, may have the greatest need for tobacco interventions. This class was disproportionately made up of young, non-Hispanic, Black, Hispanic, lower income, less educated and sexual minority adults,

¹ E-cigarettes are a type of ENDS product

which aligns with research that identifies high prevalence of tobacco use among these demographic groups (Garrett et al., 2015). The development and implementation of tobacco control interventions, such as mass media campaigns and smoke-free laws, must take into account the intersection of multiple factors, such as social marginalization, in order to reduce tobacco use among the most vulnerable groups, who often have multiple risk factors for tobacco-use (Garrett et al., 2015; Voigt, 2010). This may include targeted efforts, such as funding to support smoke-free laws in low-income areas (Brown and Barlow, 2009) and strategies to ensure that interventions are implemented equitably. It is also important that these interventions address non-cigarette tobacco products and poly tobacco use. Research is needed to evaluate the effectiveness and implementation of existing tobacco control interventions among these high-risk groups to ensure that they support health equity (Centers for Disease Control and Prevention, 2015).

For the LCA, we selected the 3-class structure based on model fit indices, OCC and interpretability. However, we also considered the 4-class model and conducted a sensitivity analysis (data not shown in this paper). The 4-class model included all 3 classes identified in the 3-class model, but contained an additional class characterized by moderate internalizing problems, moderate externalizing problems and low substance use problems. We did not select this model because the fourth group appeared to be differentiated by degree rather than having its own unique characteristics. Future studies, however, should continue to investigate different latent class models of psychopathology and how they relate to tobacco use behavior.

This study has limitations. First, this study was limited to the questions included in the modified GAIN-SS and does not assess symptoms of all psychiatric disorders. Additionally, this study did not use cutoff scores for the GAIN-SS that have been established in the literature (Dennis et al., 2006; Dennis et al.; Pearson et al., 2017). This was done purposefully since there are advantages to looking at individual symptoms of psychiatric disorders as described in the introduction; however, the established cut points for the GAIN-SS have high sensitivity and specificity and can be effective for screening for psychiatric disorders. Additionally, this study does not assess frequency or heaviness of tobacco use, which has important implications for tobacco-related health consequences and is particularly relevant when considering poly tobacco use. Future studies should explore how individuals with psychiatric comorbidities use tobacco products in terms of frequency and heaviness.

This study allowed for a holistic examination of the complex interplay of symptoms of internalizing, externalizing and substance use disorders (Lanza and Rhoades, 2013) to identify high-risk individuals who not only suffer from the negative symptoms associated with psychiatric comorbidities, but also disproportionately use tobacco products and are at greater risk for tobacco-related morbidity and mortality. Unfortunately, tobacco control interventions specifically designed for individuals with psychiatric comorbidities have been slow to develop (Williams and Ziedonis, 2004). The Clinical Practice Guidelines for Treating Tobacco Use and Dependence include guidelines for treating individuals with psychiatric disorders; however, this guidance is based on clinical diagnoses of psychiatric disorders (Fiore et al., 2008). Findings from this study suggest that symptoms of a broad range of psychiatric disorders should be considered when identifying individuals with higher risk for tobacco use in both research and clinical settings since the use of clinical diagnoses may inadvertently leave out individuals with symptom-specific issues that put them at higher risk for tobacco use, even if they do not meet the criteria for diagnosis. More research is needed to identify effective cessation programs and other tobacco control interventions for tobacco users with psychiatric comorbidities, across a range of psychiatric symptoms, disorders and tobacco products.

Funding

OG was funded in part by the George Washington University Dissertation Award. ACV was supported by the National Institute of General Medical Sciences of the National Institutes of Health under Award Number P20GM103644. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Contributors

OG conceptualized the paper, conducted the statistical analyses and wrote the first draft of the manuscript. ALJ and RNR contributed to the analysis plan and the interpretation of the data. All authors critically revised the manuscript and approved the final manuscript as submitted.

Declaration of competing interest

No conflict declared.

Acknowledgement

The authors would like to thank Dr. Vinu Ilakkuvan for her support with the latent class analysis

References

- Ameringer, K.J., Leventhal, A.M., 2013. Associations between attention deficit hyperactivity disorder symptom domains and DSM-IV lifetime substance dependence. *Am. J. Addict.* 22 (1), 23–32. <https://doi.org/10.1111/j.1521-0391.2013.00325.x>.
- Asparouhov, T., Muthén, B., 2018. Variable-specific Entropy Contribution. Retrieved from <https://www.statmodel.com/download/UnivariateEntropy.pdf> (Accessed 16 December 2018).
- Bianco, C.L., 2018. Rates of electronic cigarette use among adults with a chronic mental illness. *Addict. Behav.* <https://doi.org/10.1016/j.addbeh.2018.08.033>.
- Breslau, N., Novak, S.P., Kessler, R.C., 2004. Psychiatric disorders and stages of smoking. *Biol. Psychiatry* 55 (1), 69–76. [https://doi.org/10.1016/S0006-3223\(03\)00317-2](https://doi.org/10.1016/S0006-3223(03)00317-2).
- Brown, T.A., Barlow, D.H., 2009. A proposal for a dimensional classification system based on the shared features of the DSM-IV anxiety and mood disorders: implications for assessment and treatment. *Psychol. Assess.* 21 (3), 256–271. <https://doi.org/10.1037/a0016608>.
- Callaghan, R.C., Veldhuizen, S., Jeysingh, T., Orlan, C., Graham, C., Kakouris, G., ... Gatley, J., 2014. Patterns of tobacco-related mortality among individuals diagnosed with schizophrenia, bipolar disorder, or depression. *J. Psychiatr. Res.* 48 (1), 102–110. <https://doi.org/10.1016/j.jpsychires.2013.09.014>.
- Campion, J., Checinski, K., Nurse, J., McNeill, A., 2008. Smoking by people with mental illness and benefits of smoke-free mental health services. *Adv. Psychiatr. Treat.* 14 (3), 217–228.
- Centers for Disease Control and Prevention, 2015. Best Practices User Guide: Health Equity in Tobacco Prevention and Control. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. In, Atlanta.
- Choi, K., Sabado, M., El-Toukhy, S., Vogtmann, E., Freedman, N.D., Hatsukami, D., 2017. Tobacco product use patterns, and nicotine and tobacco-specific nitrosamine exposure: NHANES 1999–2012. *Cancer Epidemiol. Biomarkers Prev.* 26 (10), 1525–1530. <https://doi.org/10.1158/1055-9965.EPI-17-0338>.
- Collins, L.M., Lanza, S.T., 2010. Latent Class and Latent Transition Analysis: With Applications in the Social, Behavioral, and Health Sciences Vol. 718 John Wiley & Sons.
- Conway, K.P., Green, V.R., Kasza, K.A., Silveira, M.L., Borek, N., Kimmel, H.L., ... Compton, W.M., 2017. Co-occurrence of tobacco product use, substance use, and mental health problems among adults: findings from Wave 1 (2013–2014) of the Population Assessment of Tobacco and Health (PATH) Study. *Drug Alcohol Depend.* 177, 104–111. <https://doi.org/10.1016/j.drugalcdep.2017.03.032>.
- Cosgrove, V.E., Rhee, S.H., Gelhorn, H.L., Boeldt, D., Corley, R.C., Ehringer, M.A., ... Hewitt, J.K., 2011. Structure and etiology of co-occurring internalizing and externalizing disorders in adolescents. *J. Abnorm. Child Psychol.* 39 (1), 109–123. <https://doi.org/10.1007/s10802-010-9444-8>.
- Debell, F., Fear, N.T., Head, M., Batt-Rawden, S., Greenberg, N., Wessely, S., Goodwin, L., 2014. A systematic review of the comorbidity between PTSD and alcohol misuse. *Soc. Psychiatry Psychiatr. Epidemiol.* 49 (9), 1401–1425. <https://doi.org/10.1007/s00127-014-0855-7>.
- Dennis, M.L., Chan, Y.F., Funk, R.R., 2006. Development and validation of the GAIN Short Screener (GSS) for internalizing, externalizing and substance use disorders and crime/violence problems among adolescents and adults. *Am. J. Addict.* 15 (Suppl. 1), 80–91. <https://doi.org/10.1080/10550490601006055>.
- Dennis, M. L., Feeney, T., & Stevens, L. H. Global Appraisal of Individual Needs -Short

- Screening (GAIN-SS): Administration and Scoring Manual for the GAIN-SS Version 2.0. 1. Bloomington, IL: Chestnut Health Systems. http://www.chestnut.org/LL/gain/GAIN_SS/index.html (Accessed 18 October 2016). In.
- El-Gabalawy, R., Tsai, J., Harpaz-Rotem, I., Hoff, R., Sareen, J., Pietrzak, R.H., 2013. Predominant typologies of psychopathology in the United States: a latent class analysis. *J. Psychiatr. Res.* 47 (11), 1649–1657. <https://doi.org/10.1016/j.jpsychires.2013.07.028>.
- Fiore, M.C., Jaen, C.R., Baker, T.B., 2008. Treating Tobacco Use and Dependence: 2008 Update. Clinical Practice Guideline. U.S. Department of Health and Human Services. Public Health Service. In, Rockville, MD.
- Fu, Q., Vaughn, M.G., Wu, L.T., Heath, A.C., 2014. Psychiatric correlates of snuff and chewing tobacco use. *PLoS One* 9 (12), e113196. <https://doi.org/10.1371/journal.pone.0113196>.
- Garrett, B.E., Dube, S.R., Babb, S., McAfee, T., 2015. Addressing the social determinants of health to reduce tobacco-related disparities. *Nicotine Tob. Res.* 17 (8), 892–897. <https://doi.org/10.1093/ntr/ntu266>.
- Gintner, G.G., 2014. DSM-5 conceptual changes: innovations, limitations and clinical implications. *Prof. Couns.* 4 (3).
- Goniewicz, M.L., Smith, D.M., Edwards, K.C., Blount, B.C., Caldwell, K.L., Feng, J., ... Hyland, A.J., 2018. Comparison of nicotine and toxicant exposure in users of electronic cigarettes and combustible cigarettes. *JAMA Netw Open* 1 (8), e185937. <https://doi.org/10.1001/jamanetworkopen.2018.5937>.
- Hagman, B.T., Delnevo, C.D., Hrywna, M., Williams, J.M., 2008. Tobacco use among those with serious psychological distress: results from the national survey of drug use and health, 2002. *Addict. Behav.* 33 (4), 582–592. <https://doi.org/10.1016/j.addbeh.2007.11.007>.
- Hamari, A.K., Toljamo, T.I., Kinnula, V.L., Nieminen, P.A., 2013. Dual use of cigarettes and Swedish snuff (snus) among young adults in Northern Finland. *Eur. J. Public Health* 23 (5), 768–771. <https://doi.org/10.1093/eurpub/cks131>.
- Hefner, K.R., Sollazzo, A., Mullaney, S., Coker, K.L., Sofuoglu, M., 2019. E-cigarettes, alcohol use, and mental health: use and perceptions of e-cigarettes among college students, by alcohol use and mental health status. *Addict. Behav.* 91, 12–20. <https://doi.org/10.1016/j.addbeh.2018.10.040>.
- Hyland, A., Ambrose, B.K., Conway, K.P., Borek, N., Lambert, E., Carusi, C., ... Compton, W.M., 2016. Design and methods of the population assessment of tobacco and health (PATH) study. *Tob. Control*. <https://doi.org/10.1136/tobaccocontrol-2016-052934>.
- Inter-university Consortium for Political and Social Research, and Westat, 2018. Population Assessment of Tobacco and Health (PATH) Study [United States] Public-Use Files: User Guide. In, Ann Arbor, MI.
- Jané-Llopis, E., Jané-Llopis, E., Matytsina, I., Jané-Llopis, E., Matytsina, I., 2006. Mental health and alcohol, drugs and tobacco: a review of the comorbidity between mental disorders and the use of alcohol, tobacco and illicit drugs. *Drug Alcohol Rev.* 25 (6), 515–536. <https://doi.org/10.1080/09595230600944461>.
- John, U., Meyer, C., Rumpf, H.J., Hapke, U., 2004. Smoking, nicotine dependence and psychiatric comorbidity—a population-based study including smoking cessation after three years. *Drug Alcohol Depend.* 76 (3), 287–295. <https://doi.org/10.1016/j.drugaldep.2004.06.004>.
- Kasza, K.A., Ambrose, B.K., Conway, K.P., Borek, N., Taylor, K., Goniewicz, M.L., ... Hyland, A.J., 2017. Tobacco-product use by adults and youths in the United States in 2013 and 2014. *N. Engl. J. Med.* 376 (4), 342–353. <https://doi.org/10.1056/NEJMs1607538>.
- Kasza, K.A., Bansal-Travers, M., O'Connor, R.J., Compton, W.M., Kettermann, A., Borek, N., ... Hyland, A.J., 2014. Cigarette smokers' use of unconventional tobacco products and associations with quitting activity: findings from the ITC-4 U.S. Cohort. *Nicotine Tob. Res.* 16 (6), 672–681. <https://doi.org/10.1093/ntr/ntt212>.
- King, J.L., Reboussin, B.A., Spangler, J., Cornacchione Ross, J., Sutfin, E.L., 2018. Tobacco product use and mental health status among young adults. *Addict. Behav.* 77, 67–72. <https://doi.org/10.1016/j.addbeh.2017.09.012>.
- Kollins, S.H., McClernon, F.J., Fuemmeler, B.F., 2005. Association between smoking and attention-deficit/hyperactivity disorder symptoms in a population-based sample of young adults. *Arch. Gen. Psychiatry* 62 (10), 1142–1147. <https://doi.org/10.1001/archpsyc.62.10.1142>.
- Lanza, S.T., Rhoades, B.L., 2013. Latent class analysis: an alternative perspective on subgroup analysis in prevention and treatment. *Prev. Sci.* 14 (2), 157–168. <https://doi.org/10.1007/s11121-011-0201-1>.
- Lasser, K., Boyd, J.W., Woolhandler, S., Himmelstein, D.U., McCormick, D., Bor, D.H., 2000. Smoking and mental illness: a population-based prevalence study. *JAMA* 284 (20), 2606–2610.
- Lawrence, D., Mitrou, F., Zubrick, S.R., 2009. Smoking and mental illness: results from population surveys in Australia and the United States. *BMC Public Health* 9, 285. <https://doi.org/10.1186/1471-2458-9-285>.
- Magidson, J.F., Liu, S.-M., Lejeune, C., Blanco, C., 2012. Comparison of the course of substance use disorders among individuals with and without generalized anxiety disorder in a nationally representative sample. *J. Psychiatr. Res.* 46 (5), 659–666.
- McClave, A.K., McKnight-Eily, L.R., Davis, S.P., Dube, S.R., 2010. Smoking characteristics of adults with selected lifetime mental illnesses: results from the 2007 National Health Interview Survey. *Am. J. Public Health* 100 (12), 2464–2472. <https://doi.org/10.2105/AJPH.2009.188136>.
- McLean, C.P., Asnaani, A., Litz, B.T., Hofmann, S.G., 2011. Gender differences in anxiety disorders: prevalence, course of illness, comorbidity and burden of illness. *J. Psychiatr. Res.* 45 (8), 1027–1035. <https://doi.org/10.1016/j.jpsychires.2011.03.006>.
- Methodology Center, Penn State College of Health and Human Development, 2018. LCA and LTA Modeling FAQ. Retrieved from <https://methodology.psu.edu/ra/lca/model-faq> (Accessed 11 February 2019).
- Muthen, Muthen, 2018. Mplus Version 8.1.
- Mykletun, A., Overland, S., Aaro, L.E., Liabo, H.M., Stewart, R., 2008. Smoking in relation to anxiety and depression: evidence from a large population survey: the HUNT study. *Eur. Psychiatry* 23 (2), 77–84. <https://doi.org/10.1016/j.eurpsy.2007.10.005>.
- Nagin, D.S., 2005. Group-based Modeling of Development. Harvard University Press.
- Nylund-Gibson, K., Choi, A.Y., 2018. Ten frequently asked questions about latent class analysis. *Transl Issues Psychol Sci* Vol. 4, pp. 440–461.
- Nylund, K.L., Asparouhov, T., Muthen, B.O., 2007. Deciding on the number of classes in latent class analysis and growth mixture modeling: a monte carlo simulation study. *Struct. Equ. Model.* 14 (4), 535–569.
- Pacek, L.R., Wiley, J.L., McClernon, F.J., 2019. A conceptual framework for understanding multiple tobacco product use and the impact of regulatory action. *Nicotine Tob. Res.* 21 (3), 268–277. <https://doi.org/10.1093/ntr/nty129>.
- Park, S.H., Lee, L., Shearston, J.A., Weitzman, M., 2017. Patterns of electronic cigarette use and level of psychological distress. *PLoS One* 12 (3), e0173625. <https://doi.org/10.1371/journal.pone.0173625>.
- Pearson, J.L., Johnson, A., Villanti, A., Glasser, A.M., Collins, L., Cohn, A., ... Stanton, C.A., 2017. Misperceptions of harm among Natural American Spirit smokers: results from wave 1 of the Population Assessment of Tobacco and Health (PATH) study (2013–2014). *Tob. Control* 26 (e1), e61–e67. <https://doi.org/10.1136/tobaccocontrol-2016-053265>.
- Rojewski, A.M., Baldassarri, S., Cooperman, N.A., Gritz, E.R., Leone, F.T., Piper, M.E., ... Tobacco Treatment, N., 2016. Exploring issues of comorbid conditions in people who smoke. *Nicotine Tob. Res.* 18 (8), 1684–1696. <https://doi.org/10.1093/ntr/ntw016>.
- Schauer, G.L., Berg, C.J., Kegler, M.C., Donovan, D.M., Windle, M., 2015. Assessing the overlap between tobacco and marijuana: trends in patterns of co-use of tobacco and marijuana in adults from 2003–2012. *Addict. Behav.* 49, 26–32. <https://doi.org/10.1016/j.addbeh.2015.05.012>.
- Schroeder, S.A., Morris, C.D., 2010. Confronting a neglected epidemic: tobacco cessation for persons with mental illnesses and substance abuse problems. *Annu. Rev. Public Health* 31, 297–314.
- Smack, A.J., Herzhoff, K., Tang, R., Walker, R.L., Tackett, J.L., 2017. A latent class analysis of personal values in young adults. *Collabra Psychol.* 3 (1), 30. <https://doi.org/10.1525/collabra.114>.
- Smith, P.H., Mazure, C.M., McKee, S.A., 2014. Smoking and mental illness in the U.S. population. *Tob. Control* 23 (e2), e147–e153. <https://doi.org/10.1136/tobaccocontrol-2013-051466>.
- Spears, C.A., Jones, D.M., Pechacek, T.F., Ashley, D.L., 2019. Use of other combustible tobacco products among priority populations of smokers: implications for U.S. Tobacco regulatory policy. *Addict. Behav.* 93, 194–197. <https://doi.org/10.1016/j.addbeh.2019.01.031>.
- StataCorp LP, 2017. Stata/SE 15.1 for Windows. College Station, TX.
- Substance Abuse and Mental Health Services Administration, 2018. Key Substance Use and Mental Health Indicators in the United States: Results from the 2017 National Survey on Drug Use and Health (HHS Publication No. SMA 18-5068, NSDUH Series H-53). Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration. In, Rockville, MD.
- Sung, H.Y., Wang, Y., Yao, T., Lightwood, J., Max, W., 2018. Polyto tobacco use and nicotine dependence symptoms among US adults, 2012–2014. *Nicotine Tob. Res.* 20 (suppl_1), S88–S98. <https://doi.org/10.1093/ntr/nty050>.
- Talati, A., Keyes, K.M., Hasin, D.S., 2016. Changing relationships between smoking and psychiatric disorders across twentieth century birth cohorts: clinical and research implications. *Mol. Psychiatry* 21 (4), 464–471. <https://doi.org/10.1038/mp.2015.224>.
- Tam, J., Warner, K.E., Meza, R., 2016. Smoking and the reduced life expectancy of individuals with serious mental illness. *Am. J. Prev. Med.* 51 (6), 958–966. <https://doi.org/10.1016/j.amepre.2016.06.007>.
- Tomar, S.L., Alpert, H.R., Connolly, G.N., 2010. Patterns of dual use of cigarettes and smokeless tobacco among US males: findings from national surveys. *Tob. Control* 19 (2), 104–109. <https://doi.org/10.1136/tc.2009.031070>.
- U.S. Department of Health and Human Services, 2014. The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General. U.S. Department of Health and Human Services, Centers for Disease Control, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. In, Rockville (MD).
- Vaidyanathan, U., Patrick, C.J., Iacono, W.G., 2011. Patterns of comorbidity among mental disorders: a person-centered approach. *Comp Psychiatry* 52 (5), 527–535.
- Vaughn, M.G., Delisi, M., Gunterbh, T., Fu, Q., Beaver, K.M., Perron, B.E., Howard, M.O., 2011. The severe 5%: a latent class analysis of the externalizing behavior Spectrum in the United States. *J. Crim. Justice* 39 (1), 75–80. <https://doi.org/10.1016/j.jcrimjus.2010.12.001>.
- Voigt, K., 2010. Smoking and social justice. *Public Health Ethics* 3 (2), 91–106. <https://doi.org/10.1093/phe/phq006>.
- Wang, T.W., Asman, K., Gentzke, A.S., Cullen, K.A., Holder-Hayes, E., Reyes-Guzman, C., ... King, B.A., 2018. Tobacco product use among adults—United States, 2017. *MMWR Morb. Mortal. Wkly. Rep.* 67 (44), 1225.
- Weich, S., McBride, O., Hussey, D., Exeter, D., Brugha, T., McManus, S., 2011. Latent class analysis of co-morbidity in the Adult Psychiatric Morbidity Survey in England 2007: implications for DSM-5 and ICD-11. *Psychol. Med.* 41 (10), 2201–2212. <https://doi.org/10.1017/S0033291711000249>.
- Wetter, D.W., McClure, J.B., de Moor, C., Cofta-Gunn, L., Cummings, S., Cinciripini, P.M., Gritz, E.R., 2002. Concomitant use of cigarettes and smokeless tobacco: prevalence, correlates, and predictors of tobacco cessation. *Prev. Med.* 34 (6), 638–648. <https://doi.org/10.1006/pmed.2002.1032>.
- Williams, J.M., Ziedonis, D., 2004. Addressing tobacco among individuals with a mental illness or an addiction. *Addict. Behav.* 29 (6), 1067–1083.