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# Discriminability of personality profiles in isolated and Co-morbid marijuana and nicotine users



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## ABSTRACT

Specific personality traits have been linked with substance use disorders (SUDs), genetic mechanisms, and brain systems. Thus, determining the specificity of personality traits to types of SUD can advance the field towards defining SUD endophenotypes as well as understanding the brain systems involved for the development of novel treatments. Disentangling these factors is particularly important in highly co-morbid SUDs, such as marijuana and nicotine use, so treatment can occur effectively for both. This study evaluated personality traits that distinguish isolated and co-morbid use of marijuana and nicotine. To that end, we collected the NEO Five Factor Inventory in participants who used marijuana-only ( $n=59$ ), nicotine-only ( $n=27$ ), both marijuana and nicotine ( $n=28$ ), and in non-using controls ( $n=28$ ). We used factor analyses to identify personality profiles, which are linear combinations of the five NEO Factors. We then conducted Receiver Operating Characteristics (ROC) curve analysis to test accuracy of the personality factors in discriminating isolated and co-morbid marijuana and nicotine users from each other. ROC curve analysis distinguished the four groups based on their NEO personality patterns. Results showed that NEO Factor 2 (openness, extraversion, agreeableness) discriminated marijuana and marijuana+nicotine users from controls and nicotine-only users with high predictability. Additional ANOVA results showed that the openness dimension discriminated marijuana users from nicotine users. These findings suggest that personality dimensions distinguish marijuana users from nicotine users and should be considered in prevention strategies.

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## 1. Introduction

Despite the high co-morbidity between marijuana (MJ) and nicotine (NIC) use, only few studies have directly addressed the mechanisms that lead to their concurrent use. A recent review by Agrawal describes multiple etiologies that influence their co-morbidity. This includes route of administration (inhaled), cross-drug adaptation, response to treatments, environmental effects and genetic factors (Agrawal et al., 2012). Others have also alluded to the “gateway drug” hypothesis whereby the use of one drug may potentiate the effects of the other. For example, in a longitudinal study in 14–15 year olds, marijuana use increased the likelihood of initiating nicotine use up to 8 times and developing nicotine dependence up to 3 times suggesting marijuana’s role as a gateway drug (Patton et al., 2005). This was further supported by findings showing that women who used marijuana were at 4.4 odds of later developing nicotine use and dependence

(Agrawal et al., 2008). The same group also reported in 43,093 adults that nicotine smoking increased the risk for marijuana use and dependence up to 3 times (Agrawal and Lynskey, 2009). This latter finding suggests a bi-directional potentiating effect and indicates that more complex factors may drive combined use. Although the animal literature has characterized the neural mechanisms that may underlie these potentiating effects, it is also possible that personality factors contribute to this phenomenon.

Combined marijuana and nicotine use has been associated with differential effects on clinical diagnoses, cognitive and psychosocial problems, and outcomes (Ketcherside and Filbey 2015; Filbey et al., 2015; Peters et al., 2012). For example, Bonn-Miller and colleagues examined associations between negative emotions (depression and anxiety) that discriminate marijuana-only users from co-morbid marijuana and nicotine users (Bonn-Miller et al., 2010). They found that, in general, nicotine-only using individuals had significantly greater negative emotionality than marijuana users, co-morbid marijuana and nicotine users, and non-using controls. Earlier work by Degenhardt showed that while nicotine and marijuana use were both individually associated with

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increased rates of negative emotion, this relationship appeared to be driven by neuroticism in marijuana users (Degenhardt et al., 2001). Taken together, these studies argue for different patterns of co-morbidity in nicotine and marijuana using populations. To date, however, distinctions in trait markers, such as personality factors, have not yet been addressed in this ubiquitous group of co-morbid users.

These differences suggest the need for fine-tuning the ability to discriminate risk-profiles between these groups as they also relate to clinical treatment outcomes. Factors that contribute to risk profiles include personality traits that have been examined as putative markers for treatment outcomes. For example, in a prospective four-year study in 112 adults with chronic alcoholism, Krampe et al. (2006) determined that the presence of any personality disorder was associated with a decrease in four-year abstinence probability. Similarly, using the NEO Personality Inventory-Revised (NEO PI-R) Betkowska-Korpala (2012) found that following treatment, abstinent patients have higher levels of agreeableness and conscientiousness than patients who relapsed within a year following the therapy. This suggests that personality profiles have high predictive values for SUD outcomes and should be considered during treatment programs.

However, to date, only few studies have examined personality factors that distinguish marijuana from nicotine users and even fewer differentiate isolated use from combined use. In terms of isolated use, high openness but lower agreeableness and conscientiousness in marijuana users relative to non-users has been noted (Fridberg et al., 2011), suggesting that marijuana users differ from non-users on dimensions of normal personality traits as measured by the Big Five model of personality. Conversely, greater extraversion is widely reported in nicotine-only users (Smith, 1970), as well as high neuroticism (Tate et al., 1994) and impulsivity (Costa and McCrae, 1992). Studies that have performed direct contrasts between isolated marijuana and nicotine users have also shown differences between the two groups. For example, using the wide spectrum Five-Factor Model of personality, Terracciano et al. (2008) showed that nicotine users had lower conscientiousness and higher neuroticism whereas marijuana users had high openness, average neuroticism, and low agreeableness and conscientiousness. However, these studies did not examine personality factors in co-morbid nicotine and marijuana users. These traits together suggest that co-morbid users would have a personality profile endorsing high openness and neuroticism, but comparatively less of these traits than isolated users.

Personality factors are markers that can be used as endophenotypes for substance use disorders (SUDs) particularly because brain circuits involved in personality traits are also implicated in SUD (Cloninger, 1987; Dawe et al., 2004; Sher et al., 2000). For example, emergent literature has classified the Big Five personality model via machine learning techniques from resting state fMRI data (Kunisato et al., 2011; Kong et al., 2014). These studies indicate that neuroticism negatively correlated with activity in the middle frontal gyrus and precuneus; extraversion correlated positively with regional activity in the striatum, precuneus, and superior frontal gyrus; openness correlated positively with activity in the thalamus and amygdala, and negatively with the superior frontal gyrus; conscientiousness correlated positively with regional activity of the middle frontal gyrus and correlated negatively with the cerebellum (Kunisato et al., 2011). While these findings have not been consistent across studies, they suggest underlying neurobiological mechanisms/pathways that confer personality factors particularly in similar neural substrates implicated in SUD (i.e., mesocorticolimbic areas) (Korjus et al., 2015; Tingting et al., 2014).

Altogether, better understanding of the links between personality and SUD can provide understanding of the brain circuits

implicated in SUD that could improve prevention and intervention. Given the paucity in the literature on personality factors that discriminate co-morbid from isolated marijuana and nicotine use, this study examined differential NEO personality profiles in marijuana only, nicotine only, co-morbid marijuana and nicotine use and non-using controls. Because the existing literature has shown that marijuana users and nicotine users differ on openness and neuroticism, we predict that comorbid users would have a personality profile high on these two personality traits, but intermediate to that of the isolated users.

## 2. Methods

We obtained written informed consent from all participants in accordance with the Institutional Review Board (IRB) of University of New Mexico and the University of Texas at Dallas.

### 2.1. Study participants

Participants were recruited from the general community through flyers and newspaper advertisements to participate in a study to determine behavioral and neural associations of substances at the Mind Research Network in Albuquerque, New Mexico. All participants were between the ages of 18–55, without current Axis I disorders, not currently taking any psychotropic medications, and, have no history of brain injury. Because these data were collected as part of a larger fMRI study, participants were further required to be free of MRI contraindications (i.e. pregnancy, metallic implants, claustrophobia) and be right-handed. Of the 224 individuals who met study criteria, 80 participants were excluded for having a lifetime substance use disorder other than marijuana and nicotine. Two participants were also excluded due to missing data. Thus, analyses for this study were conducted on a sample size of 142 (Table 1).

We then categorized the participants into four groups based on their primary and regularly-used substance: marijuana-only ( $n=59$ ), nicotine-only ( $n=27$ ), co-morbid marijuana and nicotine ( $n=28$ ) and non-using control ( $n=28$ ) groups. For the marijuana-only group, regular marijuana use was defined as at least four times a week for the previous six months (without regular nicotine use). For the nicotine-only group, regular nicotine use was defined as smoking at least ten cigarettes per day (without regular marijuana use). The combined marijuana and nicotine group consisted of those who use both marijuana and nicotine regularly, as defined by 60 days out of the past 90 of concurrent use. The non-using control group consisted of participants that were neither regular users of marijuana or nicotine. Table 1 summarizes the substance use characteristics for all of the groups.

### 2.2. Instruments

All assessments took place in the laboratory and were not time-constrained. The typical length of time that participants took to complete questionnaires was 1.5 h (of note, the assessments reported here were collected as part of a larger neuroimaging study).

The study outcome variables consisted of groups of marijuana-only users, nicotine-only users, and, co-morbid users of marijuana and nicotine. Covariates included sex, race (White vs. Non-White), age, and years of education. Marijuana, nicotine and alcohol use was evaluated using the participant's self-reported use on the Timeline Followback as well as the Marijuana History Questionnaire (Sobell et al., 1995). Substance use disorders were evaluated using the Structured Clinical Interview for DSM-IV Disorders (SCID) (First et al., 1996). Personality traits were measured by NEO PI-R (PAR Inc., Lutz, FL, USA). The NEO PI-R scale is based on the

**Table 1**  
Demographic and substance use characteristics and NEO personality dimensions per group.

	ALL	CON	NIC	MJ	MJ+NIC	p
		(N=28)	(N=27)	(N=59)	(N=28)	
Males n (%)	85 (59.9%)	6 (21.4%)	17 (63.0%)	40 (67.8%)	22 (78.6%)	$\chi^2$ b(3)=22.95, p < 0.001
Race: White n (%)	82 (57.7%)	16 (57.1%)	17 (63.0%)	32 (54.2%)	17 (60.7%)	$\chi^2$ b(3)=0.70, p=0.872
Age in years Mean (SD)	26.52 (9.33)	30.89 (9.96)	29.70 (7.79)	24.13 (7.79) <sup>a,*</sup>	24.11 (8.14)	F(3,138) = 5.49; p=0.001
Education in years Mean (SD)	13.80 (2.47)	15.44 (1.85)	14.04 (2.28)	13.39 (2.28) <sup>a,*</sup>	12.77 (1.42) <sup>a,*</sup>	F(3,138) = 7.38; p=0.001
<b>Substance use Characteristics</b>						
Number of cigarette smoking days (out of 90) <sup>e</sup> , mean (SD)	43.73 (42.95)	–	88 (6.82) <sup>a,†</sup>	3.10 (8.00)	86.64 (7.82) <sup>a,†</sup>	F(2,111) = 1705; p < 0.001
Average number of cigarettes on smoking days <sup>e</sup> , mean (SD)	5.76 (7.32)	–	12.36 (5.62) <sup>a,†</sup>	0.76 (2.84)	9.92 (7.79) <sup>a,†</sup>	F(2,111) = 59.45; p < 0.001
Age you first smoked cigarette <sup>e</sup> , mean (SD)	14.59 (3.39)	13.93 (3.81)	14.32 (2.91)	14.70 (3.84)	14.96 (2.50)	F(3,117) = 0.373; p=0.770
Number of marijuana smoking days/week <sup>c</sup> mean (SD)	3.92 (3.14)	–	0.38 (0.86)	6.15 (1.34) <sup>a,#</sup>	6.53 (0.67) <sup>a,#</sup>	F(2,111) = 290.3; p < 0.001
Age of onset of regular marijuana use <sup>d</sup> mean (SD)	17.95 (4.15)	–	–	18.42 (4.22)	16.84 (3.83)	F(1,82) = 2.61, p=0.110
Years of regular marijuana use <sup>d</sup> , mean (SD)	5.71 (6.23)	–	–	5.20 (5.79)	6.91 (7.15)	F(1,82) = 1.319, p=0.254
Lifetime Cannabis Use Disorder Symptom Count <sup>e</sup> , mean (SD)	1.92 (2.39)	0.36 (0.83)	1.19 (1.92)	2.49 (2.42)	3.00 (2.84) <sup>a,*</sup>	F(3,138) = 9.22; p < 0.001
Drinks per day, Mean (SD) <sup>c</sup>	0.92 (1.24)	0.22 (0.52)	0.98 (1.16)	0.89 (1.14)	1.60 (1.64) <sup>a,*</sup>	F(3,138) = 6.53, p < 0.001
Number of drinking days (out of 90) <sup>c</sup> mean (SD)	18.72 (22.92)	7.82 (17.31)	20.96 (24.52)	18.08 (19.91)	28.79 (27.91) <sup>a,*</sup>	F(3,138) = 4.29; p=0.006
Average number of drinks/drinking day <sup>c</sup> mean (SD)	4.12 (5.42)	1.48 (1.35)	3.72 (2.71)	3.92 (2.80)	7.59 (10.34) <sup>a,*</sup>	F(3,138) = 6.88; p < 0.001
Lifetime Alcohol Use Disorder Symptom Count <sup>e</sup> , mean (SD)	2.40 (2.98)	1.43 (2.32)	2.81 (2.97)	2.88 (3.18)	1.96 (2.95)	F(3,138) = 1.92; p=0.129
<b>NEO Personality Inventory dimension</b>						
Neuroticism		45.72 (10.72)	51.56 (9.31)	48.78 (11.44)	51.98 (13.47)	F(3,138) = 1.79; p=0.1515
Extraversion		51.29 (7.86)	49.84 (11.19)	54.18 (8.31)	54.34 (8.59)	F(3,138) = 1.97; p=0.1213
Openness		56.56 (11.11)	54.76 (11.68)	60.08 (10.84)	59.61 (12.73)	F(3,138) = 1.65; p=0.1799
Agreeableness		53.91 (10.70)	43.53 (9.94)	47.99 (12.50)	44.67 (13.55)	F(3,138) = 4.24; p=0.0067
Conscientiousness		46.74 (11.00)	42.75 (9.75)	47.78 (10.99)	42.38 (14.01)	F(3,138) = 2.03; p=0.1124

Notes: Abbreviations: CON=Controls; NIC=nicotine use only; MJ=marijuana use only; MJ+NIC=combined marijuana and nicotine use, SD=standard deviation.

\* Indicates a significant group difference with  $p < .01$  compared to CON group.

† Indicates a significant group difference with  $p < .01$  compared to MJ group.

# Indicates a significant group difference with  $p < .01$  compared to NIC group.

<sup>a</sup> Post-hoc pairwise test with Bonferroni correction.

<sup>b</sup> Including relevant groups only.

<sup>c</sup> From the Timeline Followback.

<sup>d</sup> From the Cannabis History Questionnaire.

<sup>e</sup> From the Structured Clinical Interview for DSM-IV Psychiatric Disorders; Regular marijuana use is defined as at least once per week.

**Table 2**  
Factor loading patterns of NEO personality dimensions.

	Factor1	Factor2
NEO neuroticism	–0.81417	–0.06913
NEO extraversion	0.38943	0.64063
NEO openness	–0.29052	0.80281
NEO agreeableness	0.46458	0.47173
NEO conscientiousness	0.80864	–0.01141

Note: 1. Factor analysis used Varimax orthogonal rotation method.

theory of “The Big Five Factors” and assesses personality from a dimensional point of view. The five big dimensions addressed by the NEO are “neuroticism” (general tendency to experience negative feelings), “extraversion” (sociability, positive feelings, activity and self-confidence), “openness” (imagination, intellectual curiosity, aesthetic sensitivity, attention paid to one’s own feelings and no dogmatic behavior), “agreeableness” (interpersonal tendencies) and “conscientiousness” (forward planning, organization and ability to carry out tasks) (Costa and McCrae, 1992). We collected the NEO Five Factor Inventory (NEO-FFI) (Costa and McCrae, 1992) where each of the five dimensions consist of 12 items, rated on a five-point scale from “strongly disagree” to “strongly agree”. All NEO raw scores were converted to t-scores in order to create standardized, combined-sex adult norms as reported in Costa and McCrae (1992). The NEO has been shown to have high validity in

healthy controls (range .96–1.00) and in substance users (range 0.93–1.00) (McCrae and Costa, 1987) as well as high reliability (0.83–0.87 for Neuroticism, 0.51–0.79 for Extraversion, 0.78–0.85 for Openness, 0.66–0.78 for Agreeableness, and 0.80–0.85 for Conscientiousness) (Sneed et al., 2002).

### 2.3. Statistical analyses

Because we were interested in patterns of personality traits (i.e., personality profiles) that distinguish co-morbid users of both marijuana and nicotine from the marijuana-only or nicotine-only users, we first used a factor analysis with VARIMAX orthogonal rotation method to identify unique relationships (factor patterns) between each NEO personality dimension variable and unobserved latent factors. This method allowed us to combine these five factors into linear models that we could then test in linear regression given our sample size (De Winter et al., 2009) (Table 2). The logistic regression model was used to estimate how much the two significant personality factors derived from factor analysis discriminate marijuana-only, nicotine-only, co-morbid marijuana and nicotine users, and, controls controlling for covariates of sex, age, race, and education. Odds ratios (OR) and 95% confidence interval (CI) estimates were presented as results. Further, in order to test accuracy in personality factors’ discriminability of groups who use marijuana only from nicotine only and neither marijuana nor nicotine use, 70% of area under the Receiver Operating

Characteristic (ROC) curves was set as a minimum value for an accuracy of classification (Fawcett, 2006).

In addition to personality factor patterns as predictors, we also examined the group variance in each NEO personality dimension using Analysis of Variance (ANOVA). ANOVA was run for all five dimensions separately controlling for covariates of sex, race, age, and education. Post-hoc pairwise comparisons between two diagnosis groups were conducted if an overall group effect was statistically significant ( $p < 0.05$ ) and Tukey-Kramer adjusted  $p$  values were then reported. SAS 9.4 version (SAS Institute, Cary, NC) was used for all statistical analyses and  $p$  value less than 0.05 was set as a statistical significance level.

### 3. Results

#### 3.1. Descriptive statistics

Descriptive statistics for each group are provided in Table 1. Neither sex nor race was associated with SUD groups. Marijuana-only users were significantly younger than controls and nicotine-only users. Table 1 displays means and standard deviations of the five NEO Personality Inventory dimension scores by group. Nicotine-only and co-morbid marijuana and nicotine groups scored significantly lower on the openness dimension than non-using control group. There were no significant SUD group differences in the other NEO Personality Inventory dimensions (Table 1).

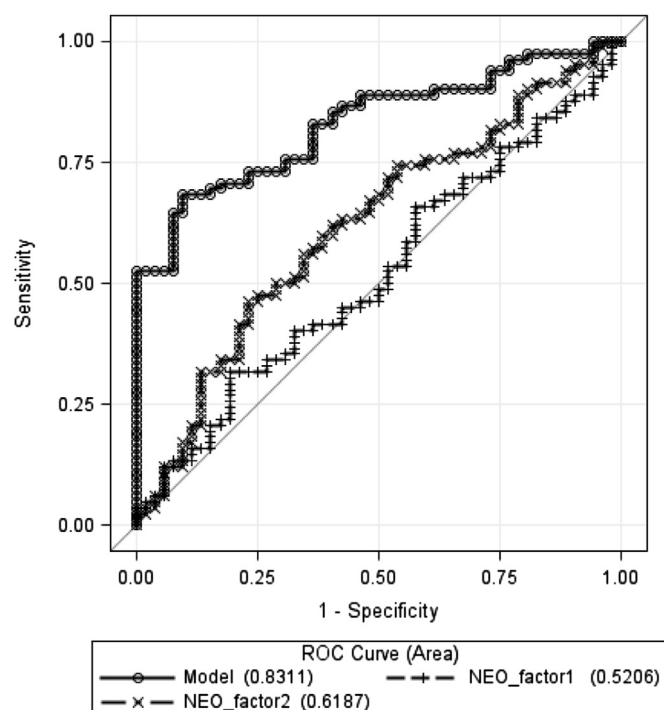
#### 3.2. Factor analysis

A factor analysis was conducted to identify personality profiles that discriminated the groups. The factor analysis identified two personality factors 1 and 2, which were linear associations of all five of neuroticism, extraversion, openness, agreeableness, and conscientiousness NEO Personality Inventory dimension  $t$  scores. Each factor-loading pattern is described in Table 3. Two dimensions, neuroticism ( $-0.81$ ) and conscientiousness ( $0.81$ ), near equally loaded high to factor 1, while the rest of dimensions, extraversion loaded the highest ( $0.64$ ), followed by openness ( $0.80$ ) and agreeableness ( $0.47$ ), loaded high to factor 2.

**Table 3**  
Logistic estimates (OR and 95% CI) of personality and covariates: four group comparisons.

Variables	Items	MJ, MJ+NIC vs CON	MJ vs NIC	MJ vs CON
Personality	Factor 1	OR (95% CI) 0.91 (0.59, 1.40)	OR (95% CI) 1.66 (0.87, 3.16)	OR (95% CI) 0.94 (0.52, 1.69)
	Factor 2	1.80 (1.12, 2.87)	1.68 (0.95, 2.96)	1.22 (0.63, 2.36)
Sex	Females	0.45 (0.19, 1.03)	0.95 (0.28, 3.17)	0.18 (0.05, 0.58)
	Males	1.00	1.00	1.00
Race	White	0.56 (0.23, 1.38)	0.40 (0.12, 1.30)	0.85 (0.26, 2.79)
	Non-White	1.00	1.00	1.00
Age	Years	0.94 (0.89, 0.99)	0.91 (0.84, 0.98)	0.95 (0.90, 1.01)
Education	Years	0.74 (0.59, 0.92)	0.97 (0.74, 1.28)	0.76 (0.57, 1.01)
$\chi^2$ (df=6) ( $p > \chi^2$ )		38.70 (< 0.001)	19.00 (0.004)	27.84 (< 0.001)

Notes: OR=Odds Ratios CI=Confidence interval.



**Fig. 1.** Area under ROC: marijuana use vs. rest of sample. Model controlled for sex, race, age, and education.

#### 3.3. Paired comparisons and logistic regression

To investigate the discriminatory effectiveness of personality factors of marijuana use among four groups (marijuana-only, nicotine-only, co-morbid marijuana and nicotine, and non-using controls), we used three paired comparisons: marijuana-only vs. all other groups, marijuana-only vs. nicotine-only, and marijuana-only vs. controls (neither marijuana nor nicotine). A logistic regression model consisted of two personality factors and covariates of sex, race, age, and education. Logistic regression results showed that as personality factor 2 score increased by 1, the odds of using marijuana increased by 180% compared to non-marijuana using groups, respectively. However, personality factor 1 did not significantly discriminate marijuana group from the other groups (Table 3). Regarding demographic variables, these comparisons also demonstrated that older participants were less likely to use marijuana, and that females had significantly lower odds than males of using marijuana only compared to neither marijuana nor nicotine use. Additionally, as years of education increased by 1 year, the odds of marijuana use decreased by 74%.

The study model was able to discriminate marijuana users from the rest with 83% accuracy, while each personality factor alone discriminated marijuana users from the rest of the sample with less than 60% accuracy (Fig. 1).

When comparing marijuana-only and nicotine-only groups, neither factor 1 nor factor 2 alone discriminated marijuana-only users from nicotine-only users with greater than 70% accuracy. However, a model with both personality factors and demographic covariates discriminated marijuana only use from nicotine users with 80% accuracy (Fig. 2).

When comparing the marijuana-only group with the control group, neither factor 1 nor factor 2 alone discriminated marijuana-only users from the control group, while a model with both personality factors and demographic covariates discriminated marijuana only use from the control group with 85% accuracy (Fig. 3).

While no significant overall group effect was found in any of

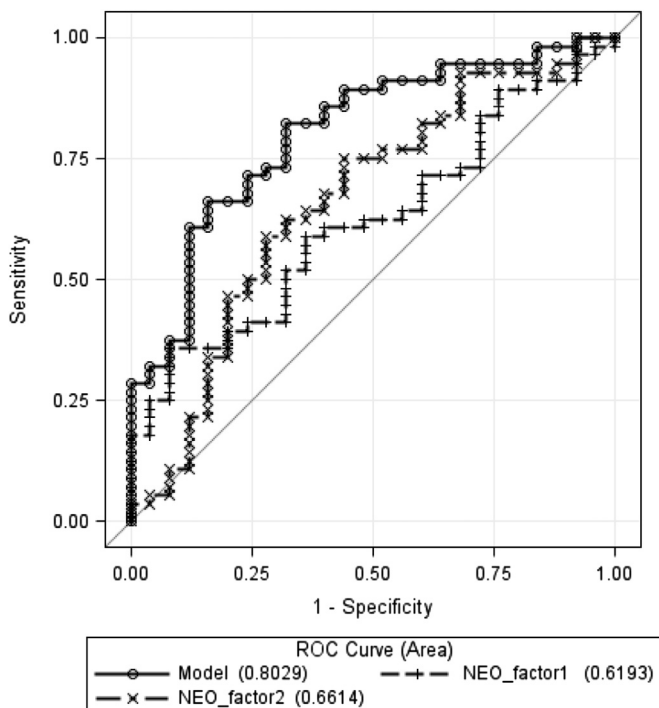


Fig. 2. Area under ROC: marijuana only use vs. cigarette only use. Model controlled for sex, race, age, and education.

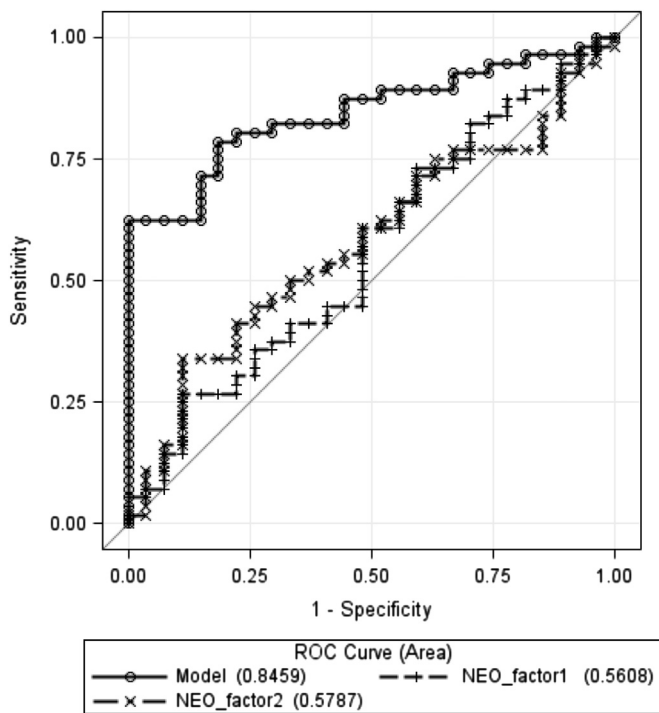


Fig. 3. Marijuana use only vs. non-substance users. Model controlled for sex, race, age, and education.

NEO agreeableness, neuroticism, extraversion, or conscientiousness *t* scores, ANOVA analysis specifically differentiated the marijuana-use group from the NIC and CON groups in the NEO openness dimension. Post-hoc pairwise group comparison showed that there was a difference between MJ and NIC groups, Tukey adjusted  $p=0.0048$ , and a trend between MJ and Control groups, Tukey adjusted  $p=0.0544$ .

Together, these observations indicate clear personality differences between individuals who use marijuana, nicotine, or both, and implicate differences in treatment between these populations.

#### 4. Discussion

The aim of this study was to determine personality profiles that distinguish marijuana users, nicotine users, and, co-morbid marijuana-nicotine users. Factor analysis showed that a model with both personality and demographic factors discriminated marijuana users from non-users better than personality factors alone. Logistic regression found strong effects of age, sex and years of education in discriminating marijuana users from non-users whereby the odds of using marijuana increased by being male, younger and less educated. A model with both personality and demographic factors also discriminated marijuana users from nicotine users with high predictability. ANOVA results showed that the openness dimension discriminated the marijuana users from all other groups and the marijuana-nicotine group from the nicotine users. These findings suggest that the discriminability of the co-morbid group from the nicotine-only and non-using group is primarily due to the contributions of marijuana use. The larger contribution of marijuana in concomitant users in terms of risk is in line with studies that found that the association between co-morbid use and negative emotion is largely driven by marijuana users (Degenhardt, et al., 2001).

Our findings are concordant with the literature that showed openness discriminates marijuana users from other groups (Fridberg et al., 2011; Terracciano et al., 2008). Openness identifies the seeking of experiences for their own sake (Costa and McCrae, 1992). Relative to marijuana, nicotine use does not have the burden of legal consequences and therefore may not require the same degree of openness as marijuana use. Our findings are also concordant with those suggesting that agreeableness and conscientiousness are lower in drug users (Fridberg et al., 2011; Terracciano et al., 2008; Bogg and Roberts, 2004). Our findings further add to this literature by showing that agreeableness and conscientiousness in marijuana users are intermediate to that of non-using controls and nicotine users (i.e., nicotine users have the lowest agreeableness and conscientiousness of the three groups). Interestingly, studies have also reported that extraversion is traditionally lower in drug users compared to non-drug users suggesting that extraversion may confer resilience to the development of addiction disorders in general (Wills et al., 1995, 2001). However, in marijuana users, the inverse effect has been observed. For instance, in a study by Terracciano et al. (2008), marijuana users exhibited greater “excitement-seeking” and “activity” (behavior related to extraversion) compared to non-users. The authors postulated that these facets of extraversion may contribute to marijuana use. Reports of marijuana use may also be more highly associated with extraversion due to the more communicative personality traits (e.g. the “gregariousness” facet) implicated in admission of illegal activity. However, in line with the studies mentioned above, the more robust effect is likely the similarly of the extraversion “excitement-seeking” facet, and sensation-seeking, which is a well established risk factor for drug use (Whiteside and Lynam, 2001).

Together with our findings of greater openness in marijuana users, we speculate potential specificity of personality traits in different substance using population. This underlines the need to characterize substance-using populations relative to each other (as opposed to non-using controls alone). Additionally, given the widely accepted association between novelty-seeking and sensation seeking in marijuana users (Donohew et al., 2000), it may be through extraversion that these risk factors lead to substance use

disorders (Belcher et al., 2014). Thus, greater sensation seeking in drug abusers would suggest that extraversion could be a risk factor (not protective factor) as others may suggest in other SUDs.

In addition to openness, other factors that discriminated marijuana users from nicotine users in our study have been linked to neurological systems responsible for appetitive-approach behaviors (Patrick et al., 2002). Recent imaging work has shown specific brain mechanisms associated with similar traits including motivation, optimism, and enthusiasm. For example, DeYoung et al. (2010) showed that extraversion scores covaried with medial orbitofrontal cortex volume, which has also been shown to be altered in long-term marijuana users (Filbey et al., 2014). Agreeableness was positively associated with retrosplenial PCC (posterior cingulate/precuneus), which is implicated in altered sensory awareness in addiction (DeWitt et al., 2015). Similarly, genetic mechanisms have also been associated with personality traits. For instance, COMT Val158Met allele has been posited to modulate extraversion (Reuter and Hennig, 2005). Together, these results suggest potential mechanisms for the association between these personality traits and marijuana use.

The current findings of greater openness in marijuana users also fit within the framework put forth in studies of marijuana use motives. Specifically, out of five putative motives for marijuana use (enhancement, coping, conformity, social, and expansion (Zvolensky et al., 2007), highest endorsements have been reported for those that require openness, such as the enhancement motive ( $M=3.53$ ), followed by social ( $M=2.38$ ) then expansion ( $M=2.02$ ) motives (Simons et al., 1998). Future studies are needed to directly examine this relationship (personality traits, marijuana use motives). However, altogether, these findings suggest that the openness personality factor is a risk marker for engagement in marijuana use (either in isolation or in combination with nicotine) as a means to expand on one's life experience (via enhancement, social, expansion reasoning).

#### 4.1. Limitations

Important considerations should be taken into account in the interpretation of these findings. First, the generalizability of these findings is limited by a predominantly white (57.7%) and highly educated sample (mean years of formal education=13.80) of participants. Future studies should consider sampling a more heterogeneous group of marijuana users. Second, it is important to note that while personality traits are often considered stable, lifelong characteristics predetermined by genetic mechanisms, others suggest that personality can be both stable and dynamic; the latter especially when influenced by drug use. Interestingly, in a study by Caselles and colleagues using a mathematical model to test the unique personality trait theory (UPTT) of addiction, they suggested a dynamic pattern of extraversion (Caselles et al., 2010) that transitions from a steady state “genetic extraversion” to “dynamic extraversion” that is influenced by substances, albeit acutely. Personality measures therefore assess a mean time value that describes the effects of substances on a long-term time scale. While the current study is not able to discriminate genetic traits from dynamic traits, this would be an important focus of study to develop better interventions. Third, as with all studies of personality, we are limited by the subjective nature of the data. Self-reported data are liable to social desirability bias. However, the NEO is a widely accepted test of personality with high validity (0.79–0.96) and high reliability (0.86–0.90) (McCrae and Costa, 2004, 1988). Future studies, however, should consider conducting a control for social desirability bias and/or collecting observer-based assessments.

#### 4.2. Conclusions

Our findings suggest that a personality pattern consisting of openness, extraversion and agreeableness separated marijuana users from nicotine users. This is a first step in delineating the factors that contribute to the high co-morbidity between the two substances. An early identification of patients bearing traits or tendencies linked to lower adaptability will decrease the possibility of relapse thanks to making a greater effort at enhancing treatment participation while paying special attention to any co-existing psychopathology.

#### Contributors

F.M. Filbey conceived and designed the study. H. Jeon-Slaughter and J.L. Baine conducted the analyses. F.M. Filbey, H. Jeon-Slaughter, and A. Ketcherside wrote the manuscript.

#### Conflict of interest

The authors do not have any conflict of interest.

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