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Comparing cigarette and e-cigarette dependence and predicting frequency of smoking and e-cigarette use in dual-users of cigarettes and e-cigarettes

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Abstract

INTRODUCTION.—The 4-item Patient-Reported Outcomes Measurement Information System Nicotine Dependence Item Bank is a psychometrically sound measure for assessing cigarette (PROMIS) and e-cigarette dependence (PROMIS-E). We evaluated whether dual-users of cigarettes and e-cigarettes self-report experiencing different levels of dependence on each product. We subsequently examined whether cigarette and e-cigarette dependence are associated with the frequency of using each product in dual-users.

METHODS.—Dual-users completed an online survey in Summer 2017 (n=326; 49.7% male, 85.3% White, mean age 38.17 [13.08] years). Measurement invariance of the PROMIS and PROMIS-E was evaluated. Mean differences in cigarette and e-cigarette dependence then were examined. The correlation between cigarette and e-cigarette dependence also was examined. Finally, one-way MANOVA was used to evaluate how cigarette and e-cigarette dependence relate to past-month frequency of e-cigarette use and cigarette smoking.

RESULTS: The PROMIS and the PROMIS-E were scalar measurement invariant, and, on average, dual-users reported stronger dependence on cigarettes than on e-cigarettes. Cigarette and e-cigarette dependence were related, yet distinct constructs (r=0.35), suggesting that dual-users can discriminate between dependence on each product. Stronger cigarette dependence predicted more frequent past-month smoking and less frequent past-month vaping. Stronger e-cigarette dependence predicted more frequent past-month vaping and less frequent smoking.

CONCLUSIONS: Overall, dual-users reported stronger dependence on cigarettes than on e-cigarettes. However, dependence on each product was associated with increased use of each respective product and with less frequent use of the other product. Future research using the

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Contributors

Drs. Morean, Krishnan-Sarin, and O'Malley contributed to the conceptualization of the study and analysis planning. Dr. Krishnan-Sarin oversaw data collection. Dr. Morean conducted the statistical analyses and wrote the initial draft manuscript. Drs. Krishnan-Sarin and O'Malley reviewed multiple drafts of the manuscript. All authors approved the final manuscript before submission.

PROMIS can evaluate how potential FDA regulations could reduce nicotine dependence across products.

Keywords

Cigarettes; Electronic Cigarettes; E-cigarettes; Vaping; Dependence; Dual-Use

1.0 INTRODUCTION

Tobacco cigarettes remain the most commonly used tobacco product among American adults, but e-cigarettes recently have gained popularity, especially among former smokers and current smokers (i.e., "dual-users")[1]. Recent estimates suggest that 17.4% of American adults currently smoke cigarettes and 5.4% use e-cigarettes[2]. Although the negative health effects of and risk for developing dependence on tobacco cigarettes are well-documented[3], the potential negative health effects of using e-cigarettes (i.e., "vaping), including their addictive potential, are not well-established[4].

To date, few studies have examined e-cigarette dependence relative to cigarette dependence. Although nicotine e-cigarette use can produce peak nicotine levels comparable to smoking cigarettes[5], research suggests that e-cigarette users experience vaping as producing less severe dependence[6–11]. However, several limitations of extant research should be noted. First, prior studies largely have relied on measures/indices of dependence that were not validated for use with both cigarettes and e-cigarettes (e.g., The Penn State E-cigarette Dependence Index[6]; the Fagerstrom Test of Nicotine Dependence[7–8]; shorter time to first morning use[9–10]). Furthermore, two studies relied on retrospective reports of cigarette dependence made by current e-cigarette users who were former smokers.[6,8] Although this approach may not be inherently invalid, it potentially raises concerns about accurate recall or about former smokers' favorable bias toward e-cigarettes, which are perceived as being safer than cigarettes[9]. Finally, although data from the nationally representative PATH study were used to compare nicotine dependence across a range of tobacco products including e-cigarettes in a sample of current product users[11], the measure that was used to assess dependence has limitations. For example, several items assess concepts that previously have been shown to be distinct from, albeit related to, nicotine dependence, including coping expectancies ("Using [product] would really help me feel better if I've been feeling down") and emotional/sensory expectancies or cognitive enhancement ("Using [product] helps me think better")[12]. In addition, different time frames are employed to assess users' experiences. For example, one item assesses past-year experiences ("In the past 12 months, did you find it difficult to keep from using [product] in places where it was prohibited") while others have a present focus ("I frequently crave [product]"). Finally, while dual-users of cigarettes and e-cigarettes answered dependence questions related to both products, it is not clear how the dependence score for dual-use was computed (e.g., a mean of both dependence scores).

Recently, the Patient-Reported Outcomes Measurement Information System (PROMIS) Nicotine Dependence Item Banks (22-item, 8-item, 4-item), which originally were developed and validated for assessing cigarette dependence[12,13], were validated for assessing e-cigarette dependence in samples of exclusive e-cigarette users and among

dual-users of both cigarettes and e-cigarettes[14]. Importantly, dual-users reported stronger e-cigarette dependence than exclusive e-cigarette users, and all e-cigarette users who reported using nicotine e-liquid reported stronger dependence than individuals using nicotine-free e-liquid[14]. However, the original PROMIS (cigarette dependence) was not administered in this earlier study, so direct comparisons of e-cigarette and cigarette dependence could not be conducted.

The current study uniquely was designed to use the PROMIS and PROMIS-E to examine differences in self-reported dependence on cigarettes and e-cigarettes, respectively, in a sample of dual-users of both products. Of note, we chose to focus on dual-users because nationally representative data suggest that the majority of e-cigarette users also are cigarette smokers[15]. Previous research indicates that the 4-item measure performs comparably to the longer versions in terms of predicting e-cigarette use outcomes (e.g., percent of variance accounted for in past 30-day vaping frequency [4-item 5%, 22-item 6%)[14], so the current study focuses on the 4-item version.

Prior to examining differences in self-reported cigarette and e-cigarette dependence in dual-users, we conducted measurement invariance analyses to ensure that making mean-level comparisons of cigarette and e-cigarette dependence was justified statistically. The magnitude of the relationship between cigarette and e-cigarette dependence was then examined as an indicator of whether dual-users could distinguish cigarette from e-cigarette dependence. Finally, research indicates that cigarette dependence is associated with increased smoking frequency[3] and that e-cigarette dependence is associated with increased vaping frequency[4]. The present study uniquely examined how dual-users' cigarette and e-cigarette dependence relate to the frequency of using each product when they are entered simultaneously as predictors.

2.0 MATERIALS AND METHODS

2.1 Participants.

Adult e-cigarette users (N=610) completed an anonymous, 20-minute, online survey. The analytic sample comprised the subsample of dual-users who reported using e-cigarettes and cigarettes at least weekly (n = 326; 49.7% male, 85.3% White, mean age 38.16 [13.09] years, smoking frequency = 22.32 [9.58] days/month, vaping frequency = 22.39 [8.33] days/month).

2.2 Procedures.

The Yale School of Medicine Institutional Review Board exempted the study. Participants were recruited by Qualtrics Online Sample, the research division of *Qualtrics, Inc.* To become a panelist, individuals voluntarily applied via the Qualtrics website and completed a "profiling" demographic survey. Qualtrics sent recruitment emails to panelists who were likely to be eligible based on their responses to previous surveys (e.g., smoking status). Interested panelists clicked on a link and completed the study eligibility questions. Participants provided consent to participate and were compensated based on the terms of their agreements with Qualtrics.

2.3 Measures.

Participants completed eligibility questions followed by questions assessing demographics, cigarette, and e-cigarette use. Remaining questionnaires (e.g., PROMIS; PROMIS-E) were completed in randomized order.

2.3.1 Screener Questions (E-cigarette and Cigarette Use)[14].—Participants completed several filler questions to obscure the study aims (e.g., vegetable consumption). Two screening questions were used to determine eligibility. First, participants had to report vaping at least weekly on the following question: "On average, how often do you use electronic cigarettes (also known as vaping)?" Response options included "never, 1–2 times per year, or 3–11 times per year, once a month, 2–3 times a month, once a week or more." To continue the survey, participants also had to provide a consistent response on the following question, which was presented later in the survey: "During the past 30 days, on how many days did you use an e-cigarette/vape? (must respond ≥ 4). All participants also answered a screener question assessing cigarette smoking status: "Which of the following best describes you? "I have never smoked a cigarette," "I am a former smoker, but I successfully quit smoking," "I smoke cigarettes occasionally - at least once a month," or "I smoke cigarettes daily." To be considered a dual-user for the current study, participants had to endorse smoking on the screener and report smoking an average of at least once a week on following question that was asked later in the survey: "During the past 30 days, on how many days did you use an e-cigarette/vape?" (must respond ≥ 4).

2.3.2 Demographic Information.—Participants reported their age (# years), biological sex (female/male), and race (which was dichotomized into Non-White/White).

2.3.3 The PROMIS and PROMIS-E[12–14].—Participants completed the four-item PROMIS measure of cigarette dependence and the four-item PROMIS-E measure of e-cigarette dependence using a 5-point rating scale (0 = never, 1 = rarely, 2 = sometimes, 3 = often, 4 = almost always). See Table 1 for the PROMIS-E items. Each measure is scored by taking the mean of the four items.

2.3.4 Nicotine E-liquid Use[14].—Given that nicotine use is associated with e-cigarette dependence and vaping frequency, participants reported whether they typically use nicotine e-liquid (no/yes).

2.4 Data Analytic Plan.

Descriptive statistics were run on all study variables.

Before comparing cigarette and e-cigarette dependence, we evaluated whether the PROMIS was invariant by product type (PROMIS [cigarettes] vs. PROMIS-E [e-cigarettes]). To account for the dependent nature of the PROMIS and PROMIS-E data, we ran a series of multiple indicator confirmatory factor analytic models within M*plus* 7.4[16] in which the latent structures of the PROMIS and the PROMIS-E were compared to one another within a single-group framework. Conceptually, this modeling examines invariance of the latent structure over time (i.e., repeated measures) rather than between groups. Ultimately, we

assessed three levels of invariance: configural (i.e., invariance of the 4-item, single-factor structure for cigarettes and e-cigarettes), metric (i.e., invariance of the magnitudes of the item factor loadings for cigarettes and e-cigarettes), and scalar (invariance of the magnitudes of item factor loadings and intercepts for cigarettes and e-cigarettes). Note that establishing scalar invariance is required before making mean-level comparisons.

For all models, we specified robust maximum-likelihood estimation and full-information maximum-likelihood for processing missing data (< 1%). Configural invariance was established if the model fit the data (i.e., Root Mean Square Error of Approximation [RMSEA] < .08; Bentler's Comparative Fit Index [CFI] ≥ .95; Standardized Root Mean Square Residual [SRMR] < .08)[17]. Metric invariance was established if constraining item factor loadings to equality did not degrade model fit by CFI ≥ .01, RMSEA ≥ .015, or SRMR ≥ .030. Scalar invariance was established if constraining item factor loadings and intercepts to equality did not degrade model fit by CFI > .010 (accompanied by changes in RMSEA ≥ .015 or SRMR ≥ .010)[18].

Once scalar invariance was established, the internal consistencies of the PROMIS and PROMIS-E were examined. Next, a paired-samples t-test was run to evaluate mean-level differences in cigarette dependence (PROMIS) and e-cigarette dependence (PROMIS-E) scores. A Pearson product-moment correlation was then run to examine the convergence (i.e., shared variance) between cigarette dependence (PROMIS) and e-cigarette dependence (PROMIS-E). Finally, a one-way MANOVA was run in which sex, age, race, and e-liquid nicotine content, cigarette dependence (PROMIS), and e-cigarette dependence (PROMIS-E) were entered simultaneously as predictors of two outcomes: smoking frequency and vaping frequency (# days/past 30 days).

3.0 RESULTS

Descriptive statistics for all study variables are presented in Table 1.

Fit indices demonstrated that the PROMIS/PROMIS-E was scalar invariant for cigarettes and e-cigarettes (Configural: RMSEA [0.049], CFI [0.991], SRMR [0.036]; Metric: RMSEA [0.047], CFI [0.990], SRMR [0.040]; Scalar: RMSEA [0.057], CFI [0.983], SRMR [0.42]). The PROMIS (α = 0.92) and PROMIS-E (α = 0.89) evidenced good internal consistency. Paired-samples t-tests indicated that dual-users reported stronger cigarette dependence (*M*[SD] = 2.40[1.18]) than e-cigarette dependence (*M*[SD] = 1.86[1.16], $t = 7.41$, $p < .01$). The Pearson product-moment correlation indicated that the PROMIS and PROMIS-E shared modest variance ($r = 0.35$; 12.2%).

When considering the MANOVA, multivariate results indicated that age ($\Lambda_{Pillai} = 0.06$), e-cigarette dependence ($\Lambda_{Pillai} = 0.15$), and cigarette dependence ($\Lambda_{Pillai} = 0.26$) were significantly related to the joint outcomes of past-month cigarette and e-cigarette use frequency (*p*-values < .001). Univariate effects indicated that age was a significant predictor of smoking frequency ($\eta_p^2 = 0.06$) whereas both e-cigarette and cigarette dependence were associated with smoking frequency and vaping frequency (e-cigarette dependence: vaping frequency [$\eta_p^2 = 0.12$]; smoking frequency [$\eta_p^2 = 0.03$]; cigarette dependence:

vaping frequency [$\eta_p^2 = 0.03$]; smoking frequency [$\eta_p^2 = 0.24$], *p*-values < .01, Table 2). Ultimately, stronger e-cigarette dependence was associated with more frequent vaping but less frequent smoking (Vaping $t = 6.46$; Smoking: $t = -3.04$) while stronger cigarette dependence was associated with more frequent smoking but less frequent vaping (Vaping: $t = -2.72$; Smoking: $t = 9.80$), all *p*-values < .010).

4.0 DISCUSSION

The current study was the first to directly compare cigarette and e-cigarette dependence in a sample of dual-users using psychometrically sound measures of both cigarette and e-cigarette dependence. Invariance analyses confirmed that cigarette and e-cigarette dependence could be compared meaningfully. Dual-users reported stronger dependence on cigarettes than on e-cigarettes, which is consistent with research comparing dependence across samples of exclusive cigarette smokers and exclusive e-cigarette users[7,8,10,14]. Providing additional evidence that dual-users can differentiate between cigarette and e-cigarette dependence, the PROMIS and PROMIS-E shared minimal variance (12.2%), suggesting that cigarette and e-cigarette dependence are related, yet distinguishable, constructs.

Consistent with prior research, stronger cigarette dependence was associated with more frequent smoking and stronger e-cigarette dependence was associated with more frequent vaping[3–4]. Further, stronger e-cigarette dependence simultaneously was associated with less frequent smoking. It is possible that these effects were driven by e-cigarette users who are trying to cut down or stop smoking cigarettes, although this hypothesis could not be tested directly in the current study. In addition, stronger cigarette dependence was associated with decreased vaping frequency. This effect points to the possibility that some individuals who are highly dependent on cigarettes may find it difficult to switch to using e-cigarettes exclusively or may be using e-cigarettes more infrequently for reasons like preventing nicotine withdrawal in locations where smoking is not permitted (i.e., circumventing smoke-free laws).

The study findings should be considered in light of several limitations. First, the self-report data were limited by participants' ability and desire to respond accurately. Second, data were gathered online, so self-reported cigarette and e-cigarette use were not confirmed biochemically. Third, although participants appeared to provide good quality data (i.e., there were few missing data, responses to similar questions were consistent), the generalizability of the findings may be limited by the sampling methods. Fourth, given that cigarette and e-cigarette dependence both are linked to nicotine use, it is possible that using one product increases vulnerability to dependence on the other. Fifth, the current study conceptualized dual-use as using both cigarettes and e-cigarettes at least weekly during the past month. However, future research should examine how the results generalize to heavier dual-users (e.g., daily users of both products). Sixth, comparisons of cigarette and e-cigarette dependence across subsamples of exclusive smokers and exclusive e-cigarette users were not possible because a subsample of exclusive smokers was not recruited for the current study. Finally, the wording of several PROMIS-E items may limit its utility. For example, the second PROMIS-E item ("I drop everything to go out and buy e-cigarettes or

e-juice") may not be applicable to individuals who purchase vaping supplies online. Further, in translating the PROMIS to the PROMIS-E, we replaced the original word "cigarette" with "e-cigarette" and the original words "smoke/smoking" with "vape/vaping." This approach may be problematic for a subset of individuals who consider themselves to be vapers but not e-cigarette users, which could result in an underreporting of dependence symptoms.

Irrespective of its limitations, the current study provides evidence that jointly using the PROMIS and PROMIS-E has utility for assessing and comparing cigarette and e-cigarette dependence. The current study makes an important contribution to the field, with findings suggesting that cigarette dependence is experienced as stronger than e-cigarette dependence among dual-users. Further, stronger e-cigarette dependence was associated with more frequent e-cigarette use but less frequent smoking, while stronger cigarette dependence was associated with more frequent smoking but less frequent vaping. Future longitudinal research examining variants of the PROMIS for assessing dependence on nicotine via cigarettes (PROMIS), e-cigarettes (PROMIS-E), and other tobacco products like cigarillos and hookah (requiring further adaptations of the instrument) may help us understand differential risk for developing dependence across multiple tobacco products, especially among dual- or poly-tobacco users. The results of such studies may inform efforts by the FDA to decrease dependence risk across products.

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Conflict of Interest

Dr. O'Malley is a member of the American Society of Clinical Psychopharmacology work group supported by Alkermes, Amygdala, Arbor Pharma, Ethypharm, Indivior, Lundbeck, and Otsuka; has received donated study medications from AstraZeneca and Pfizer; and has been a consultant/advisory member to Alkermes, Amygdala, Cerecor, Mitsubishi Tanabe, and Opiant. Drs. Krishnan-Sarin and Morean have no conflicts of interest to report.

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HIGHLIGHTS

- Most e-cigarette (ecig) users also smoke tobacco cigarettes (i.e., are dual-users).
- Dual-users could discriminate between dependence on cigarettes and e-cigs.
- Dual-users reported stronger dependence on cigarettes than on e-cigs.
- Ecig dependence predicted increased ecig but decreased cigarette use frequency.
- Cigarette dependence predicted increased cigarette but decreased ecig use frequency.

Table 1.

Descriptive statistics for central study variables within the total sample of dual-users (N = 326)

	% or *M*(*SD*)	Range (%)
Sex (% Male)	49.7%	
Age	38.16 (13.09)	18 years (0.6%) – 76 years (0.6%)
Race (% White)	85.3%	
Smoking Frequency (past 30 days)	22.32 (9.58)	4 days (5.5%) – 30 days (51.2%)
Vaping Frequency (past 30 days)	22.39 (8.33)	4 days (1.8%) –30 days (42.6%)
Nicotine E-liquid Use	83.4%	
PROMIS	2.40 (1.18)	Mean score of 0 (5.2%) – 4 (13.5%)
1. I find myself reaching for a cigarette without thinking about it.	2.47 (1.31)	Never (10.1%) – Almost Always (28.8%)
2. I drop everything to go out and buy cigarettes.	2.25 (1.33)	Never (12.3%) – Almost Always (24.5%)
3. I smoke more before going into a situation where smoking is not allowed.	2.53 (1.29)	Never (9.5%) – Almost Always (30.4%)
4. When I haven't been able to smoke for a few hours, the craving gets intolerable.	2.36 (1.31)	Never (11.7%) – Almost Always (25.8%)
PROMIS-E	1.86 (1.16)	Mean score of 0 (9.2%) – 4 (4.6%)
1. I find myself reaching for my e-cigarette without thinking about it.	2.11 (1.34)	Never (18.4%) – Almost Always (17.8%)
2. I drop everything to go out and buy e-cigarettes or e-juice.	1.53 (1.35)	Never (29.8%) – Almost Always (12.3%)
3. I vape more before going into a situation where vaping is not allowed.	2.13 (1.30)	Never (16.0%) – Almost Always (17.8%)
4. When I haven't been able to vape for a few hours, the craving gets intolerable.	1.66 (1.36)	Never (26.1%) – Almost Always (13.8%)

Table 2.

E-cigarette and cigarette dependence predicting smoking and vaping frequency

Independent Variables	Days of Use	F	η_p^2	*t*
Sex	*E-cigarette*	0.11	.00	0.03
	Cigarette	2.98	.01	1.73
Age	*E-cigarette*	0.75	.00	0.86
	Cigarette	19.26	.06***	4.39***
Race	*E-cigarette*	3.77	.01	−1.94
	Cigarette	0.43	.00	−0.65
Nicotine E-liquid Use	*E-cigarette*	1.51	.01	−1.23
	Cigarette	0.24	.00	−0.16
E-cigarette Dependence (PROMIS-E)	*E-cigarette*	41.69	.12***	6.46***
	Cigarette	9.26	.03***	−3.04**
Cigarette Dependence (PROMIS)	*E-cigarette*	7.37	.03**	−2.72**
	Cigarette	96.04	.24***	9.80***

Note. Reference groups are females (for sex) and non-White individuals (for race).

** $p < .01$

*** $p < .001$