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Relations Amongst Cigarette Dependence, e-Cigarette Dependence and Key Dependence Criteria Amongst Dual Users of Combustible and e-Cigarettes

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Abstract

Objective: To examine dependence on combustible and e-cigarettes among users of both products (dual users), which may provide important insights into long-term use patterns.

Methods: Dual users (smoking daily for 3 months, using e-cigarettes at least once/week for the past month; N=256; 45% women, 71% White, mean age 39.0 years) not interested in quitting either product, participated in a longitudinal, 2-year, observational study. At baseline, participants completed measures of combustible and e-cigarette dependence (Fagerstrom Test of Cigarette Dependence [FTCD], e-FTCD, Wisconsin Inventory of Smoking Dependence Motives [WISDM], e-WISDM, Penn State Cigarette Dependence Index [PS-CDI], and PS-ECDI) and carried a study smartphone for 2 weeks to record cigarette and e-cigarette use events.

Results: Most measures of dependence were product specific (e.g., FTCD and e-FTCD were not correlated, r=−0.003) and predicted product-specific outcomes (e.g., long-term use of that product). However, individuals used the two products for some of the same secondary dependence motives (e.g., weight control, cognitive and affective enhancement). These secondary, or instrumental, motives predicted use of both products at 1 year. Which product was used first in the morning was strongly related to product dependence scores and likelihood of continued product use at 1 year.

Conclusions: Amongst dual users of combustible and e-cigarettes, measures of e-cigarette and cigarette dependence tended to be unrelated to one another but dual users tended to use both products for the same instrumental motives. Which product is used first in the morning may serve as a valuable measure of relative dependence on the two products.

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Public Health Significance: This study illustrates that dependence on combustible and electronic cigarettes may not be related among adults who both smoke and vape. Which product they use first thing after they wake up indicates which product they are more dependent upon.

Keywords

E-cigarettes; cigarettes; dependence; dual use

Understanding the nature of drug dependence and its assessment is critical because it may lead to insights into the nature of addiction and how treatments can be developed and used to combat it. It also may allow for prediction of important outcomes such as the protracted, heavy use of an addictive agent and associated problems, which could have important implications for regulatory policies. While considerable progress has been made in understanding the nature of cigarette dependence among adults (Baker, Breslau, Covey, & Shiffman, 2012; Piasecki, Piper, & Baker, 2010a; Piper et al., 2008; Shiftman, Waters, & Hickcox, 2004), relatively little research has been done on adult e-cigarette dependence. E-cigarette dependence is of considerable clinical and public health importance since e-cigarette use has grown exponentially (Adkison et al., 2013; Ayers, Ribisl, & Brownstein, 2011; Mirbolouk et al., 2018; Wang et al., 2018).

In addition to understanding e-cigarette dependence, it is important to understand the construct of dependence among users of multiple nicotine products (i.e., dual users of combustible and electronic cigarettes), given the increasing popularity of dual use (Lee, Hebert, Nonnemaker, & Kim, 2014) or multiproduct use (Pacek, Villanti & McClernon, 2019) and the fact that more than half of e-cigarette users are also current cigarette smokers (Centers for Disease Control and Prevention, 2017; Mirbolouk et al., 2018). Pacek, Wiley & McClernon (2019) proposed a model for conceptualizing and assessing the use of multiple products, noting that it is vital to relate relevant measures to fine-grained use patterns obtained via ecological momentary assessment and to transitions in use patterns across time (e.g., cessation). They also advocate investigating how the use of one product is related to the use and effects of a second product (reciprocal effects). Consistent with this framework, the current research compared targeted, product-specific dependence measures with real-time use measures for both cigarettes and e-cigarettes. Such real-time use data permit examination of competitive or additive effects of measures of combustible and e-cigarette dependence on important use consequences or criteria (e.g., how dependence on the two products is related to product-specific outcomes such as continued use or exposure to toxicants that are specific to combustible cigarettes). For instance, is the development of strong levels of e-cigarette dependence amongst dual users associated with weaker cigarette dependence, raising the possibility that e-cigarette dependence might supplant cigarette dependence? Alternately, there is evidence that dual users who have been highly dependent on cigarettes are most likely to develop strong dependence on e-cigarettes, which might suggest not only commonalities across the motivational bases of the two types of dependence (Strong et al., 2015; Strong et al., 2017), but also indicates which smokers may be most likely to develop strong dependence on e-cigarettes and have the greatest difficulty in quitting them. Thus, measures of dependence on the two types of products could provide evidence as to the substitutability of one product for the other or the likelihood of cessation

of one or both products. But, such utilities depend upon the measures being valid indices of the target dependence constructs.

Real-time data, along with measures of combustible and e-cigarette dependence and key long-term use and nicotine and combustible cigarette-specific (i.e., toxicant) exposure outcomes, will allow us to address the question of whether dual users are dependent on nicotine, *per se*, delivered via any route or whether dependence among dual users is product specific. Strong and his colleagues (Strong et al., 2015; Strong et al., 2017) identified a single set of items (e.g., loss of control, craving, withdrawal, tolerance) that appeared to index a single primary latent dependence construct related to the use of a variety of nicotine products. This unidimensional set of items was related to a dependence criterion (e.g., heavy product use; Strong et al., 2017) across the various product use groups (exclusive smokers, dual users of cigarettes and e-cigarettes, smokeless users).

The approach of this paper has different goals. Instead of trying to identify items that index the same dependence dimension across products, we are interested in determining how well each type of dependence measure (cigarette vs. e-cigarette) predicts criteria for both its targeted type of dependence and how each predicts criteria for dependence on the other product. *That is, to what extent is dependence level product-specific?* This issue is relevant to understanding whether both forms of dependence reflect common person factors; e.g., do the same pharmacologic processes drive dependence on both types of products or are relations competitive as one type of dependence may supplant the other? This research also went beyond formal dependence measures in an effort to identify other measures or items that reflect dependence on each product (cigarettes, e-cigarettes). This research will also show the relative and net influences of the two types of dependence on important biologic markers of nicotine dependence and harmful consequences of use.

We will also examine the potential multidimensionality of dependence across products. Combustible cigarette dependence has been shown to be multidimensional, with a primary dependence factor that is related to heavy, automatic smoking that is out of control and produces strong cravings. A secondary dependence factor is related to smoking for instrumental reasons such as affective regulation, cognitive regulation, and social cues (Piper et al., 2008). Across multiple studies these dependence dimensions have been shown to share different relations with key dependence criteria such as withdrawal severity, duration of product use, and relapse likelihood (Baker, Piper, et al., 2012; Piasecki et al., 2010a; Piasecki, Piper, & Baker, 2010b; Piasecki, Piper, Baker, & Hunt-Carter, 2011; Piper et al., 2008). It is unknown how primary and secondary dependence motives for e-cigarette use are related to combustible cigarette dependence motives and use patterns.

The goal of the current research is to understand how combustible and e-cigarette dependence are related to one another among dual users of combustible and e-cigarettes. We also wanted to understand further the nomological network of dependence among dual users and how these product-specific measures of dependence might be related to important dependence criteria such as nicotine and toxicant exposure biomarkers, first product used in the morning, and use transitions over a one-year follow-up interval (see Table 1 for a list of

the constructs in the nomological network). Such information could provide insight into why dual users continue to use either or both of the two products and potential foci for treatment.

Method

This research was approved by the Institutional Review Board. Smokers and dual users of combustible and e-cigarettes were recruited for this longitudinal, 2-year observational trial via television and social media (e.g., Facebook) advertisements from October, 2015 to July, 2017. Eligibility criteria included: ≥ 18 years old, able to read and write English, have *no* plans to quit smoking and/or e-cigarette use in the next 30 days, not currently using smoking cessation medication, and not currently in treatment for psychosis or bipolar disorder. Participants had to be a smoker (i.e., smoked at least 5 cigarettes per day for the past 6 months) who had not used e-cigarettes within the last 6 months or a dual user (used nicotine-containing e-cigarettes at least once a week for the past month and have smoked daily for the last 3 months). This definition of dual user was intended to ensure the sample represented dual users who had developed a regular e-cigarette use pattern rather than smokers who used e-cigarettes more infrequently or had just started using e-cigarettes. We had initially set a minimum of 5 cigarettes/day for dual users but in order to increase recruitment, approximately 6 months into our 2-year recruitment we loosened the cigarettes/day criteria for dual users so that they just needed to have smoked daily for the last 3 months.

Eligible participants provided informed written consent and completed baseline assessments of demographics, smoking and e-cigarette history, cigarette and e-cigarette use patterns, and beliefs about cigarettes and e-cigarettes. All participants completed the FTCD (Fagerstrom, 2012), the Brief WISDM (Piper et al., 2004; Smith et al., 2010), and the PS-CDI (Foulds et al., 2015). Dual users also completed three parallel e-cigarette dependence measures: the e-FTCD, the e-WISDM (Hendricks personal communication (Piper, Baker, Benowitz, Smith, & Jorenby, 2019), which is based on the full-length WISDM (Piper et al., 2008) and the PS-ECDI (Foulds et al., 2015). The WISDM and e-WISDM both provide subscales that assess primary dependence (i.e., heavy, automatic smoking; Primary Dependence Motives [PDM]) and secondary dependence motives (i.e., instrumental smoking; Secondary Dependence Motives [SDM]).

Participants also completed assessments of dependence criteria including heaviness of use, continued use, and first product used in the morning. To assess heaviness of use, all participants provided a breath sample for carbon monoxide (CO) determination and a urine sample for baseline assessments of cotinine and the molar sum of cotinine and 3-hydroxycotinine (3HC) to examine nicotine intake independent of individual metabolic differences, and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol and its glucuronides (total NNAL), a measure of tobacco smoke exposure, which is correlated with daily intake of nicotine from cigarette smoking (Benowitz, et al. in press; Benowitz, et al., 2011). Urine cotinine, 3HC and total NNAL were measured using liquid chromatograpy-mass spectrometry in the Clinical Pharmacology Laboratory at the University of California San Francisco (Jacob et al., 2008; Jacob et al., 2011). To assess first product used in the morning, participants were asked to carry a smartphone and record each cigarette and e-cigarette

use event for 2 weeks as part of an ecological momentary assessment (EMA). Participants completed follow-up phone assessments at Months 2, 6, 10, 14, 18, and 22 and in-person assessments at Months 4, 8, 12, 16, 20, and 24. Follow-up assessments included measures of affect, withdrawal, and product use. For this research, we analyzed self-reported smoking and vaping in the 30 days prior to the Month 12 visit.

Analytic Plan

Only dual users were included in these analyses. To examine the associations between combustible and e-cigarette dependence we examined the correlations between the combustible and e-cigarette versions of the three dependence measures (FTCD vs. e-FTCD, WISDM vs. e-WISDM, PS-CDI vs. PS-ECDI). Next we examined whether combustible and e-cigarette dependence measures predict product-specific outcomes (e.g., e-cigarette dependence measures predict heaviness of use and e-cigarette use at 1 year while combustible cigarette dependence measures predict combustible outcomes) or outcomes for both products (e.g., FTCD predicts both combustible and e-cigarette use at 1 year) using logistic regression for binary outcomes and zero-order regression for continuous outcomes. Also, correlations were examined between combustible and e-cigarette dependence measures and biomarkers of nicotine exposure (cotinine and molar sum of 3HC and cotinine) and combustible cigarette smoke exposure (NNAL). Finally, because considerable evidence shows that morning product use (e.g., latency to smoke in the morning (Baker et al., 2007) is highly associated with other dependence criteria we examined which product participants used first in the morning based on their EMA data. We coded dual users into 3 groups: high morning vapers = vaping first and smoked later on at least 50% of mornings; low morning vapers = vaping first on fewer than 50% of mornings; and exclusive smoking first = reporting smoking first every morning and used oneway ANOVAs and chi-square tests to analyze the associations of the dependence measures with which product is used first in the morning.

Results

A total of 5959 people responded to study advertisements. We were able to screen 2042 and 1065 were eligible per the phone screen and 422 enrolled. Of the 256 dual users in this study, 45% were women, 71% were White, 13% were Black, 7% were Hispanic, 66% had more than a high school degree, and 61% had a self-reported history of receiving a diagnosis of, or treatment for, a psychiatric condition. Participants were a mean 39.0 (SD=13.8) years of age and smoked a mean 12.5 (SD=7.4) cigarettes per day and vaped a mean 10.2 (SD=14.2) times per day with 55.5% reporting vaping every day. Dual users reported using the following e-cigarette types: a refillable tank (65.3%), a replaceable cartridge (19.2%), or disposables (11.4%); this research was conducted before JUUL and nicotine salt products were available. The vast majority (96%) of the participants were smokers before trying e-cigarettes. Due to a database coding error only 183 dual users completed the e-WISDM and PS-ECDI and only 177 completed the e-FTCD; all available data were analyzed.

Relations of Cigarette and e-Cigarette Dependence Measures.

The correlations of the combustible vs. e-cigarette dependence measures indicated that the measures that substantially reflect heaviness of product use (cigarette or e-cigarette) were not related to one another (i.e., the FTCD/e-FTCD, the PS-CDI/PS-ECDI, and the WISDM PDM/e-WISDM PDM: see Table 2). This lack of association is consistent with the lack of association between participants' report of their heaviest cigarettes smoked per day and vapes per day (r=.02, p=.78). However, the WISDM SDM and e-WISDM SDM showed a fairly strong positive relation. Examination of the correlations of the SDM subscale scores across the combustible and e-cigarette dependence measures revealed that instrumental use motives such as affective regulation, cognitive control, and weight control motivations were especially highly correlated across products (Table 2). Taste motives were not correlated across products.

Prediction of Continued Use of Cigarettes at 1 Year Follow-up.

Of the 205 dual users (69%) who reported Year 1 use data (i.e., self-report use of combustible and e-cigarettes for the last 30 days), 112 (54.6%) were still vaping and 93 had quit vaping. Therefore, at 1 year, 100 (39%) dual users had smoked and vaped in the last 30 days, 90 (35%) had just smoked, 12 (5%) had just vaped, and 3 (1%) had not used either product (see Piper, Baker, Benowitz, & Jorenby, 2019). Most combustible cigarette dependence measures predicted likelihood of becoming abstinent from combustible cigarettes at one-year follow-up (Table 3). The relations were especially strong for the FTCD, the PS-CDI, and the WISDM PDM. All these measures assess heaviness of smoking and thus, their results are consistent with the strong relation between self-reported cigarettes/day and 1-year abstinence (Table 3). The FTCD, the PS-CDI, the WISDM, and the WISDM PDM were no longer significant predictors of Year 1 smoking once cigarettes/day at baseline was entered into the model. The WISDM SDM measure does not assess smoking heaviness and did not significantly predict 1-year smoking status.

The measures of e-cigarette dependence were not predictive of later smoking status, nor was self-reported vaping heaviness *per se* predictive of future smoking status.

Prediction of Continued Use of e-Cigarettes at 1 Year Follow-Up.

All the e-cigarette dependence measures predicted participants' continued use of e-cigarettes at 1-year with the PS-ECDI and the e-WISDM-PDM showing especially strong relations (Table 3). Since these scales assess heaviness of vaping, these relations are consistent with the significant relation observed between self-reported vaping/day and 1-year abstinence. In essence, the more a dual user vaped at baseline, the more likely the person was to continue vaping. This raises the question of whether the dependence measures carry information about e-cigarette use that is not captured by the vaping/day measure. When vapes/day was entered as a covariate, the e-WISDM PDM (OR=.88, 95% CI=.80-.98, p =.02) remained a significant predictor but the PS-ECDI did not (OR=.86, 95% CI=.72-1.04, p =.11). Conversely, the vapes/day measure was no longer a significant predictor of 1-year vaping status when the e-WISDM PDM was entered into the prediction model, suggesting that the predictive validity of the e-WISDM PDM depended on its assessment of content domains beyond heaviness of use per se.

The measure of secondary dependence (i.e., instrumental dependence motives), the e-WISDM SDM, was predictive of 1-year vaping status. In addition, secondary dependence on *cigarettes* (WISDM SDM) was related to greater likelihood of stopping *vaping* at one year (Table 3). To further explore this finding, we examined the relations of e-cigarette outcomes at 1 year with each WISDM SDM subscale. This revealed that two subscales were especially related to discontinuing e-cigarettes at 1-year: smoking to control weight (OR=1.21, 95% CI=1.04-1.42, p=.02) and smoking for taste/sensory processes (OR=1.18, 95% CI=.99-1.40, p=.06). Thus, to the extent that weight control and taste motives were important motives for a person's smoking, that dual user was relatively unlikely to continue using e-cigarettes.

Relations of Dependence Measures with Biomarkers of Nicotine and Combustible Cigarette Exposure.

In general, nicotine exposure biomarkers (i.e., cotinine and the molar sum of cotinine and 3HC) were significantly associated with measures of cigarette dependence that focus on heaviness of use, including self-reported cigarettes/day (Table 4: see Piper, Baker, Benowitz, Kobinsky, & Jorenby, 2019 for the absolute biomarker levels). The WISDM and the WISDM SDM was not associated with either nicotine use biomarker. Levels of the toxicant NNAL, a biomarker of combustible cigarette exposure, were positively associated with all measures of cigarette dependence and with self-reported cigarettes/day but not with WISDM SDM. None of the e-cigarette dependence measures were associated with the nicotine exposure biomarkers, but all of the e-cigarette dependence measures were associated with decreased NNAL, indicating that strong e-cigarette dependence is associated with lower NNAL values (i.e., less exposure to combustible cigarette smoke). This was not driven entirely by heaviness of e-cigarette use as the relation between self-reported vapes/day and NNAL was not significant.

To determine whether dependence on cigarettes and e-cigarettes each contributes orthogonal predictive information about NNAL, we entered both FTCD and e-FTCD into a regression model predicting NNAL. This revealed that both contributed significantly to the model, in opposite directions (FTCD: B=.36, p<.001, e-FTCD: B=−.20, p=.01). These results were similar for the other scales (PS-CDI: B=.35, p<.001, PS-ECDI: B=−.14, p=.05; WISDM: B=.22, p=.01, e-WISDM: B=−.24. p=.002; WISDM PDM: B=.33, p<.001; e-WISDM PDM: B=−.22, p=.002).

Relations of Dependence Measures with Morning Product Use.

The product that dual users reported using first in the morning (i.e., combustible or e-cigarette) via EMA was strongly related to the various dependence measures (see Table 5). In essence, to the extent that dual users vaped first in the morning rather than smoked first, they had meaningfully lower cigarette dependence scores, higher e-cigarette dependence scores, and were less likely to be smoking at the 1-year follow-up and were more likely to continue vaping (Table 5). Conversely, dual users who exclusively smoked first in the morning had especially high cigarette dependence scores and relatively low e-cigarette dependence scores. Moreover, of those dual users who exclusively smoked first in the morning, 100% were still smoking at 1-year follow-up. Dual users who vaped first on

some mornings, but fewer than half, had dependence scores more similar to dual users who exclusively smoked first in the morning.

Discussion

One goal of this research was to clarify the relations between cigarette and e-cigarette dependence amongst adult dual users of both products. That is, we wanted to understand how dependence measures for the two different products were related to one another amongst those using both (i.e., the extent to which a measure of dependence on one product predicts the use of, or dependence on, the other product). Results could have shown that those who become highly dependent on one product tend to be highly dependent on the other, reflecting a general disposition toward nicotine dependence. Or, the results could have shown a negative relation as one type of dependence tends to supplant the other. The results, in fact, largely show negligible relations between dependence on the two products. Thus, there is little evidence of an association between psychometric measures of dependence on one product and psychometric measures of the other product at a given point in time (e.g., baseline), at least with regard to measures that are heavily influenced by amount of product use (the e-FTCD, the PS-ECDI, and the WISDM PDM). Although there is little association between measures that reflect primary dependence (the WISDM PDM and the e-WISDM PDM), there is a meaningful association between measures of secondary, or instrumental, dependence with regard to the two products (the WISDM SDM and the e-WISDM SDM).

The WISDM/e-WISDM secondary dependence measures show a fairly strong association between cigarette and e-cigarette dependence. Thus, smokers tend to use both nicotine products for the same instrumental reasons. In particular, they tend to use both products to control weight and enhance affect and cognition. This association, in the context of little association with regard to primary dependence, suggests that the use of e-cigarettes in these dual users is largely due to conscious decision making to achieve certain instrumental goals but that e-cigarette use in this sample was not heavy enough to yield primary dependence, which is associated with long-term heavy use and unconscious or automatic processing (Baker et al., 2012; Piasecki et al., 2010a,b, 2011; Piper et al., 2004, 2008). This construction is consistent with evidence that secondary dependence precedes the development of primary dependence (Piasecki et al., 2001; Piper et al., 2008). On the other hand, the data show that to the extent that secondary motives are important for smoking they predict decreased likelihood of continued e-cigarette use over the course of a year. In other words, dual users may have turned to e-cigarettes to achieve instrumental goals such a weight control but for many dual users, e-cigarettes ultimately disappoint them in that regard.

There is additional evidence of cross-product relations. As noted, most cigarette dependence measures consistently predict higher levels of both nicotine use (cotinine, cotinine+3HC) and exposure to combustible cigarettes (NNAL). However, e-cigarette use and dependence were not significantly related to the nicotine exposure biomarkers but e-cigarette dependence was negatively related to NNAL (see Piper et al., 2019). Thus, displacement of smoking by e-cigarettes can be observed in the lower levels of NNAL, the biomarker of exposure to combusted tobacco. In fact, analyses showed that e-cigarette and cigarette dependence

measures yielded complementary effects when both were used in prediction models: the more individuals smoked the higher their NNAL and more they vaped, the lower their NNAL. It is unknown whether the amount of reduction in NNAL or possibly other toxicants associated with combustible cigarette use, is sufficient to have health effects over time.

As noted earlier, Strong et al., (Strong et al., 2015; Strong et al., 2017) identified sets of dependence items that predicted dependence for a variety of different nicotine delivery products. Our research did not examine how well a single set of items assesses dependence across the different tobacco products, but instead we examined whether dependence focused on one product (e.g., e-cigarettes) is related to dependence measures focused on another product (e.g., cigarettes) amongst adults who use both. As noted above, our results show considerable independence of dependence on the two products. This may reflect the influence of factors specific to each product or it may greatly reflect the characteristics of this sample: dual users who typically used cigarettes heavily before trying e-cigarettes and then using the latter modestly.

Another goal of this work was to obtain additional evidence on the validity of the different dependence measures (the FTCD/e-FTCD, the PS-CDI/PS-ECDI, and the WISDM/e-WISDM measures). Consistent with the suggestions of Pacek et al. (Pacek et al., 2019), we used EMA data to examine real-world product use and relate such use to dependence measures. Latency to smoke after awakening has been a consistent and accurate predictor of other cigarette dependence measures and criteria such as likelihood of smoking cessation (e.g., Baker et al., 2007). In the present research, the tendency to vape first in the morning rather than smoke was associated with higher e-cigarette dependence scores and lower cigarette dependence scores. In addition, vaping first was associated with a higher likelihood of discontinuing smoking at 1-year follow-up. Conversely, the tendency of dual users to smoke exclusively first in the morning (versus vape) was associated with higher cigarette dependence scores and relatively low e-cigarette dependence scores. Thus, these data provide another example of the reciprocal relations between the use of the two products. Which product is used first in the morning may serve as a valuable measure of relative dependence on the two products.

These findings regarding the importance of first product used in the morning stand in contrast to research by Strong and colleagues (Strong et al., 2017) who found that the item ‘time to first use’ of tobacco was not highly related to other dependence indicators across a range of nicotine products. There are many reasons that this item may not have served as a universal index of dependence (e.g., the metric in minutes may not have been appropriate for some products). The current research suggests that *relative* latency to use different tobacco products may index *relative* dependence in poly-product users.

The strong predictive relations of the combustible cigarette and e-cigarette dependence measures that are highly influenced by heaviness of product use (e.g., FTCD/e-FTCD, the PS-CDI/PS-ECDI, and the WISDM PDM/e-WISDM PDM measures) reflect the importance of highly repetitive use as indexing dependence (Baker, Breslau, et al., 2012; Baker, Piper, et al., 2012) perhaps reflecting the importance of the strong stimulus-response bonds that undergird habit learning (Baker, Breslau, et al., 2012; Everitt & Robbins, 2005). However,

the present research suggests that dual users may initiate e-cigarette use to achieve specific instrumental ends that are satisfied by cigarettes, and the effectiveness of this substitution affects the future use of e-cigarettes.

These findings must be interpreted in light of the study limitations. First, our findings may be highly sample dependent. Observed relations might vary greatly in a population with a longer history of e-cigarettes use or one that used e-cigarettes that deliver greater amounts of nicotine (e.g., JUUL) or among adolescents. Second, this research was conducted before JUUL and nicotine salt products were available, which may be more rewarding (Hajek, et al., 2020). This may influence the rewarding value of e-cigarettes and therefore the relations with primary and secondary dependence motives. Third, because of loss of data due to a database error, and attrition over follow-up, statistical power was more limited than intended. Finally, the relatively small sample size limits generalizability. In sum, the results of this research are useful for the purpose of hypothesis generation but not for drawing firm conclusions. Future research is needed to examine the relations between e-cigarette and combustible cigarette dependence in a larger sample that includes users of nicotine salt products.

In conclusion, amongst dual users of combustible and e-cigarettes, questionnaire measures of cigarette dependence and e-cigarette dependence were generally not strongly related to one another. However, there was evidence that individuals used both products to achieve similar instrumental goals (e.g., weight control, cognitive and affective enhancement) and such motives were associated with the future use of e-cigarettes. Which product was used first in the morning may serve as an indicator of relative dependence on the two products and predicts the likelihood of continued product use 1 year later. The results from this study may suggest strategies for assessing the ‘transfer’ of use or dependence across different nicotine products, facilitating such transfer, and predicting future product use.

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Table 1.

Constructs in the nicotine dependence nomological network for dual users.

Measure	Construct	Details
Fagerstrom Test of Cigarette Dependence (FTCD)	Cigarette dependence	6-item measure, administered at baseline
Penn State Cigarette Dependence Index (PS-CDI)	Cigarette dependence	10-item measure, administered at baseline
Brief Wisconsin Inventory of Smoking Dependence Motives (WISDM)	Cigarette dependence	37-item measure, administered at baseline, 2 factors: Primary Dependence Motives and Secondary Dependence Motives
Fagerstrom Test of E-Cigarette Dependence (e-FTCD)	E-cigarette dependence	6-item measure, administered at baseline
Penn State E-Cigarette Dependence Index (PS-ECDI)	E-cigarette dependence	10-item measure, administered at baseline
Brief Wisconsin Inventory of Smoking E-cigarette Dependence Motives (e-WISDM)	E-cigarette dependence	37-item measure, administered at baseline, 2 factors: Primary Dependence Motives and Secondary Dependence Motives
Cigarettes/day	Smoking heaviness (cigarette dependence criterion)	Assessed at baseline and Year 1
Vapes/day	Vaping heaviness (e-cigarette dependence criterion)	Assessed at baseline and Year 1
Cotinine	Heaviness of use – nicotine exposure (dependence criterion)	Assessed at baseline and Year 1
Molar sum of cotinine and3HC	Heaviness of use – nicotine exposure (dependence criterion)	Assessed at baseline and Year 1
NNAL	Heaviness of combustible tobacco use, exposure to toxicants (cigarette dependence criterion)	Assessed at baseline and Year 1
Ecological momentary assessment of first product used each morning	First product used in the morning (dependence criterion)	Assessed for 2 weeks at baseline
Smoking at Year 1	Continued use (cigarette dependence criterion)	Assessed at Year 1
Vaping at Year 1	Continued use (e-cigarette dependence criterion)	Assessed at Year 1

Table 2.

Correlations between combustible and e-cigarette dependence measures (N's = 176-183)

Dependence Measures	Correlation	p-value
FTCD vs. e-FTCD	−.005	.94
PS-CDI vs. PS-ECDI	−.03	.70
WISDM vs e-WISDM	.26	< .001
WISDM PDM vs. e-WISDM PDM	.09	.24
WISDM SDM vs. e-WISDM SDM	.40	< .001
WISDM Affiliative Attachment vs. e-WISDM Affiliative Attachment	.46	<.001
WISDM Affective Enhancement vs. e-WISDM Affective Enhancement	.53	<.001
WISDM Cognitive Enhancement vs. e-WISDM Cognitive Enhancement	.47	<.001
WISDM Cue Exposure vs. e-WISDM Cue Exposure	.39	<.001
WISDM Social/Environmental Goads vs. e-WISDM Social/Environmental Goads	.35	<.001
WISDM Taste/Sensory Processes vs. e-WISDM Taste/Sensory Processes	−.02	.84
WISDM Weight Control vs. e-WISDM Weight Control	.70	<.001

FTCD = Fagerstrom Test of Cigarette Dependence, PS-CDI = Penn State Cigarette Dependence Index, PS-ECDI = Penn State Electronic Cigarette Dependence Index, WISDM = Wisconsin Inventory of Dependence Motives, PDM = Primary Dependence Motives (Automaticity, Craving, Loss of Control, Tolerance), SDM = Secondary Dependence Motives (Affiliative Attachment, Affective Enhancement, Cognitive Enhancement, Cue Exposure, Social/Environmental Goads, Taste/Sensory Processes, Weight Control)

Table 3.

Predicting 30-day point-prevalence abstinence from combustible and e-cigarettes at 1 year (N's=141-205)

	Combustible Cigarette Abstinence			E-Cigarette Abstinence		
	OR	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
FTCD	.69	.54-.90	.01	1.01	.90-1.13	.86
PS-CDI	.78	.67-.90	.001	1.01	.95-1.08	.68
WISDM	.96	.92-1.00	.07	1.02	1.00-1.04	.13
WISDM PDM	.60	41-.87	.01	1.03	.85-1.24	.77
WISDM SDM	.80	.52-1.25	.34	1.30	1.03-1.64	.03
Cigarettes/day	.82	.72-.93	.002	1.02	.98-1.05	.42
e-FTCD	1.08	.82-1.42	.58	.76	.63-.92	.01
PS-ECDI	1.07	.96-1.20	.22	.65	.76-.93	<.001
e-WISDM	1.03	.99-1.07	.18	.96	.93-.99	.01
e-WISDM PDM	1.29	.91-1.81	.15	.62	.46-.83	.002
e-WISDM SDM	1.30	.82-2.07	.26	.70	.51-.97	.03
Vapes/day	1.00	.96-1.04	.95	.94	.89-.99	.03

Note. FTCD = Fagerström Test ot Cigarette Dependence, PS-CDI = Penn State Cigarette Dependence Index, PS-ECDI = Penn State Electronic Cigarette Dependence Index, WISDM = Wisconsin Inventory of Dependence Motives, PDM = Primary Dependence Motives (Automaticity, Craving, Loss of Control, Tolerance), SDM = Secondary Dependence Motives (Affiliative Attachment, Affective Enhancement, Cognitive Enhancement, Cue Exposure, Social/Environmental Goads, Taste/Sensory Processes, Weight Control)

Table 4.

Correlations with baseline biomarkers of exposure to nicotine and combustible cigarettes (N's = 167-253)

	Cotinine		Molar sum of cotinine and 3HC		NNAL	
	Correlation	**p-value**	**Correlation**	**p-valu**	**Correlation**	**p-value**
FTCD	.30	<.001	.25	<.001	.33	<.001
PS-CDI	.25	<.001	.27	<.001	.35	<.001
WISDM	.08	.20	.06	.32	.14	.03
WISDM PDM	.18	.01	.16	.01	.26	<.001
WISDM SDM	.04	.45	−.01	.83	.03	.68
Cigarettes/day	.25	<.001	.24	<.001	.37	<.001
e-FTCD	−.09	.24	−.05	.52	−.20	.01
PS-ECDI	−.03	.67	−.002	.98	−.16	.04
e-WISDM	−.14	.07	−.13	.09	−.18	.02
e-WISDM PDM	−.14	.06	−.13	.09	−.20	.01
e-WISDM SDM	−.12	.10	−.12	.13	−.15	.045
Vapes/day	−.05	.53	−.03	.73	−.13	.09

Note. FTCD = Fagerstrom Test of Cigarette Dependence, PS-CDI = Penn State Cigarette Dependence Index, PS-ECDI = Penn State Electronic Cigarette Dependence Index, WISDM = Wisconsin Inventory of Dependence Motives, PDM = Primary Dependence Motives (Automaticity, Craving, Loss of Control, Tolerance), SDM = Secondary Dependence Motives (Affiliative Attachment, Affective Enhancement, Cognitive Enhancement, Cue Exposure, Social/Environmental Goads, Taste/Sensory Processes, Weight Control)

Table 5.

Dependence scores based on morning vaping status

	High morning vape (vape first on at least 50% of mornings; n=41)	Low morning vape (vape first on fewer than 50% of mornings; n=79)	Exclusive smoking first (n=51)	F or χ^2	P-value
FTCD	2.6 (2.2)[ab]	4.6 (2.5)	4.8 (2.2)	12.67	<0.001
PS-CDI	7.5 (4.1)[ab]	12.0 (3.8)	12.2 (3.6)	22.42	<0.001
WISDM	38.0 (12.8)[ab]	47.6 (12.5)	48.7 (12.7)	9.89	<0.001
WISDM PDM	3.4 (1.5)[ab]	4.6 (1.5)	4.8 (1.3)	11.90	<0.001
WISDM SDM	3.5 (1.1)[ab]	4.2 (1.1)	4.2 (1.2)	6.43	0.002
Cigarettes/day	6.3 (4.8)[ab]	14.2 (7.9)	13.5 (6.6)	19.20	<0.001
Smoking at Year 1 (%)	68.6	95.7	100.0	27.22	<0.001
e-FTCD	4.3 (2.3)[ab]	2.2 (2.0)	2.2 (1.7)	15.90	<0.001
PS-ECDI	10.3 (4.7)[ab]	6.2 (4.5)	5.1 (4.1)	15.13	<0.001
e-WISDM	39.0 (14.5)[ab]	31.5 (12.1)	29.2 (13.1)	6.23	0.003
e-WISDM PDM	3.8 (1.7)[ab]	2.6 (1.3)	2.3 (1.3)	11.99	<0.001
e-WISDM SDM	3.4 (1.2)	3.0 (1.1)	2.9 (1.2)	2.62	0.08
Vapes/day	17.3 (18.9)[a]	10.2 (16.7)	5.6 (5.6)	5.55	0.005
Vaping at Year 1 (%)	94.3	60.9	55.3	15.83	<0.001

[a]Post-hoc analyses showed a significant difference between High morning vape and Low morning vape

[b]Post-hoc analyses showed a significant difference between High morning vape and Exclusive morning smoking

Note. FTCD = Fagerstrom Test of Cigarette Dependence, PS-CDI = Penn State Cigarette Dependence Index, PS-ECDI = Penn State Electronic Cigarette Dependence Index, WISDM = Wisconsin Inventory of Dependence Motives, PDM = Primary Dependence Motives (Automaticity, Craving, Loss of Control, Tolerance), SDM = Secondary Dependence Motives (Affiliative Attachment, Affective Enhancement, Cognitive Enhancement, Cue Exposure, Social/Environmental Goads, Taste/Sensory Processes, Weight Control)