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Original Article

Using the Theory of Planned Behavior to Anticipate DIY E-juice Mixing among Young Adult International E-cigarette Users

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Abstract

Background: Trends in young adult use of electronic nicotine delivery systems (ENDS) and experimentation with do-it-yourself (DIY) e-juice mixing are growing around the world. Theoretical frameworks for examining secondary behaviors (i.e., mixing) embedded within a primary behavior (i.e., vaping) are limited, leading to challenges in scholarly understanding of behavioral performance. This study explored the theoretically driven factors surrounding ENDS users' decision to mix DIY e-juice through a multiple behavior test of the theory of planned behavior (TPB).

Methods: An international sample of young adult participants aged 18-19 (n=203) was recruited from Prolific for an online cross-sectional survey. Path modeling tested four theoretically driven models to explore behavioral performance of mixing.

Findings: The data supported TPB expectations and revealed new paths for secondary behavior. Primary perceptions of attitudes, norms, and intention were predictive of the same secondary perceptions. In addition, for both primary and secondary behaviors, perceived norms were a function of perceived attitudes. For the secondary behavior, normative influence was experienced indirectly through perceived attitudes.

Conclusion: DIY e-juice mixing is a product of perceived attitudes and behavioral control surrounding mixing as well as perceived attitudes, norms, and intention surrounding general ENDS use. While unregulated DIY experimentation increases among youth, these findings provide a lens for public health efforts seeking to reach and reduce use. Understanding DIY e-juice behaviors is essential to anticipate stockpiling behaviors and negative outcomes from amateur experimentation.

Keywords: Vaping, Electronic nicotine delivery systems, Behavior, E-cig use

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Introduction

Electronic nicotine delivery systems (ENDS; e.g., vapes, hookah pens, e-cigarettes) are noncombustible tobacco products that heat liquid concentrates to deliver chemical ingredients.[1] The liquids in ENDS devices (known as e-liquids or e-juice) typically include cannabidiol, tetrahydrocannabinol (THC), nicotine, or a permutation of the three along with a flavor ingredient and fogging agent.[2] The use of ENDS products has been steadily growing over the last decade, particularly among young adults, with an estimated 35 million global users and global sales are expected to pass 40 billion dollars by 2023.[3] Flavored tobacco products are well documented for their ability to entice young adult users.[4] Although there are calls to ban the sale of flavored ENDS products,[5] ENDS are not included in all regulated flavor bans. The lack of regulation has led the way for increased user experimentation of flavored e-juice, particularly do-it-yourself (DIY) e-juice mixing where users create their own flavor profiles and concentration preferences.

DIY e-juice is an expanding behavior within the ENDS community that involves users mixing their own ENDS e-juice.[6] The mixing process includes three key components: a fogging agent (e.g., propylene glycol, vegetable glycerin), nicotine concentrate, and flavoring agents.[2,7] Users then balance these components to achieve the desired taste, nicotine concentration, and throat hit. The extent to which ENDS users are choosing to mix their own e-juice over purchasing is currently unknown but the proliferation of online forums, such as the DIY e-juice mixing communities on Reddit[8] and Discord,[9] suggest that the trend is growing around the world exhibiting characteristics of a hobbyist mentality among young adult ENDS users.[6,10] While mixing is typically legal, there is a growing public health concern over the inaccuracy of e-juice labels and the amateur mixing of chemicals.

Research has found discrepancies in the lab tests of labeled concentrations.[6,7,11,12] One study found of 72

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different nicotine-based e-juices, 64% contained higher than labeled concentrations of nicotine with 65% deviating by more than 10%.[13] In a follow-up study that tested 30 e-juices labeled as nicotine-free, four contained nicotine.[7] In addition to discrepancies in labeled concentration levels, concern is growing over ENDS users inhaling different chemical combinations that, although possibly safe to ingest, have unknown inhalation effects.[2,14] For instance, in fall 2019, the US was inundated with hospitalizations and deaths associated with ENDS use. Six months after the initial outbreak, 'e-cigarette, or vaping, product use-associated lung injury' (EVALI) accounted for 2,668 hospitalizations and 68 deaths.[15] Eventually, public health and tobacco control researchers identified the most likely cause to be users who created their own DIY e-juice by mixing vitamin E acetate as an additive into their THC-based ENDS liquid.[14] Although vitamin E acetate is safe to ingest, the inhalation implications were previously unknown.

Studies grounded in behavior change theory are needed to understand behavioral processes of these high-risk users that will undoubtedly continue to be a priority focus of the tobacco prevention community. Although non-ENDS users can mix e-juice, recipes can only be tested by those who use an ENDS product. Thus, understanding behavioral processes surrounding DIY e-juice mixing is an extension of the first understanding of behavioral processes surrounding ENDS use. Health behavior theories taking multiple behavioral approaches that center on embedded behaviors are limited.[16] Given past research documenting the roll of the theory of planned behavior (TPB) in understanding tobacco-related behaviors,[17-19] this framework provides a starting point for exploring the underlying behavioral processes of DIY e-juice mixing among young adult ENDS users.

The TPB[20,21] approaches human behavior as an outcome of rational decision making. Specifically, the TPB posits that attitude (i.e., the degree to which one has a favorable or unfavorable evaluation of a behavior), subjective norms (i.e., the perceived pressure to perform a behavior with perceived normative performance of a behavior), and behavioral control (i.e., the degree to which one feels performing the behavior will be easy or difficult) predict behavioral intention (i.e., the intent to perform a behavior), which in turn predicts behavioral performance. Occasionally, behavioral control directly predicts actual behavior. The TPB has been supported as an effective framework for understanding various behavioral outcomes (see extensive reviews[22-24]; see meta-analytic investigations[25-28]), including tobacco-related behaviors (see examples[29]; see meta-analysis[17-19]), with difference in model fit varying across behaviors, sampling designs, and operationalization of TPB constructs. However, TPB investigations typically focus on a single behavior as opposed to a multiple behavioral approach.[16] The extent to which behavior is a product of the complex relationships between other health-related behaviors should not be overlooked or undervalued. The act of mixing DIY e-juice is a prime example of the nested complexities of embedded behaviors in that the processes surrounding mixing DIY e-juice cannot be separated from the processes surrounding the decision to use an ENDS product.

The purpose of this study was to test a multiple behavior approach of the TPB to explore the theoretical processes surrounding the behavior of DIY e-juice mixing. The guiding research question sought to explore the extent to which the data would fit a multiple behavior model following the foundational expectations of the TPB.

Without past research to guide further hypotheses and relationships, Figure 1 displays the model that served as a starting point to be tested against rival models containing the same constructs. This model expects the TPB relationships in the context of ENDS use to predict the TPB relationships in the context of DIY e-juice mixing.

Methods

Procedures

Participant sampling occurred on "Prolific", an online research recruitment service that allows individuals from around the world to participate in survey research for

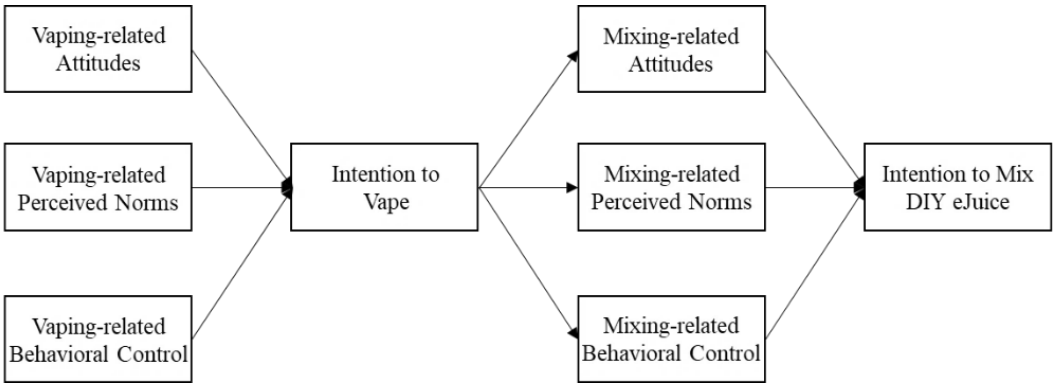

Figure 1. Theory of planned behavior-based predictions of intention to Mix DIY e-juice

monetary compensation. Prolific is designed to solicit responses only from participants that meet pre-established recruitment criteria. All Prolific users complete studies from the locations and computers of their choosing. Upon receiving Institutional Review Board approval, participants were recruited in October 2020 from Prolific through a multi-step process. First, participants had to be at least 18 years old and have ever vaped (n = 582 of the 148 648 participants in the pool). Next, 582 participants were invited to complete an eligibility survey reporting their DIY e-juice mixing history. Participants (n = 337) were provided with a definition of DIY e-juice mixing (i.e., *mixing your own nicotine-based liquid for a vape cartridge*) with 188 reporting having mixed e-juice at least once in the last three years. Among the 151 participants who had not reported mixing in the last three years, the first 50 were selected to be grouped with the 188. This was done to include a range of mixing intention among participants (without over representing non-DIY e-juice mixers) which in turn helps normalize the distribution, allowing for parametric statistical tests to better function without data transformation. This is preferable to data transformation because the 50 participants represent an actual data set of individuals' intention and behaviors. Finally, these participants (n = 238) were invited to complete the full survey with 203 consenting and fully completing it (85% participation rate). Although ENDS is the comprehensive term used by regulatory agencies, the survey referred to ENDS use more colloquially as vaping.

Measures

All TPB variables measured two nested behaviors: vaping and mixing DIY e-juice. Variables were operationalized both in the context of vaping and DIY e-juice (e.g., attitudes towards vaping and attitudes towards mixing). All measures were adapted to the context of the study.[24] Across all adapted items for all four latent variables, response options were on a 5-point Likert scale from *strongly disagree* to *strongly agree*.

Attitudes

Eight items were used to assess attitudes toward vaping (e.g., *vaping is a positive behavior, it is good to vape*). Cronbach's alpha was on the low end of acceptable, but still supported scale reliability ($\alpha = 0.703$); a composite mean for vaping-related attitudes was created (m = 3.11, SD = 0.61). Regarding attitudes toward mixing DIY e-juice, seven items were adapted, excluding a secondhand exposure-related item from the vaping behavior adaptation (e.g., *mixing my own e-juice is a positive behavior, mixing my own e-juice is healthy*). Cronbach's alpha supported scale reliability ($\alpha = 0.742$); a composite mean for mixing-related attitudes was created (m = 3.77, SD = 0.57).

Perceived norms

For vaping and mixing-related perceived norms, injunctive (i.e., [referent group] *thinks it is okay if I vape/mix my own DIY e-juice*) and descriptive (i.e., [referent group] *vapes/mixes their own DIY e-juice*) norms were assessed for three distinct referent groups: *people my age*, *my close friends*, and *my immediate family*. For both behaviors, the average among injunctive and descriptive norms were the highest among people of the same age (vaping: m = 4.50, SD = 0.61; mixing: m = 3.96, SD = 0.85) and close friends (vaping: m = 4.27, SD = 0.80; mixing: m = 3.59, SD = 1.04) compared to immediate family (vaping: m = 2.22, SD = 1.04; mixing: m = 2.18, SD = 1.06). To capture comprehensive normative influences, responses to the six behavior-related items were averaged, creating a composite mean for vaping- (m = 3.66, SD = 0.52) and mixing-related perceived norms (m = 3.24, SD = 0.75).

Behavioral control

Behavioral control regarding vaping was assessed via four items (e.g., *I am confident I could quit vaping at any time, I can say no to vaping, even if I was the only one in a group not vaping)*. Cronbach's alpha supported scale reliability ($\alpha = 0.785$); a composite mean for vaping-related behavioral control was created (m = 3.53, SD = 0.99). Six items were used to assess behavioral control related to mixing DIY e-juice with two extra items reflecting a comparison to buying e-juice (e.g., *I would be okay never mixing my own e-juice again*, *I could go back to only buying e-juice, even if I was the only person I knew not mixing their own liquid)*. Cronbach's alpha supported scale reliability ($\alpha = 0.771$); a composite mean for mixing-related behavioral control was created (m = 3.89, SD = 0.93).

Behavioral intention

Three items were used to assess vaping and mixing-related behavioral intention. The participants were asked to respond to their level of agreement with the statements, '*I intend to continue [vaping/mixing my own e-juice],*' '*I am likely to [vape/mix my own e-juice] again*,' and '*I have no plans to quit [vaping/mixing my own e-juice].*' Cronbach's alpha supported scale reliability for vaping- ($\alpha = 0.797$; m = 3.67, SD = 0.95) and mixing-related ($\alpha = 0.754$; m = 3.25, SD = 1.19) behavioral intentions.

Data analysis

Descriptive and exploratory analyses were performed in SPSS V 27; path model analyses were performed in AMOS V 27.[30] Path analysis modeling followed maximum likelihood estimations to explore theoretically expected routes. To assess model fit, the indicators of chi-square, standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA), goodness

of fit index (GFI), and comparative fit index (CFI) were examined.[31] Several steps were taken to enhance study validity. First, data collection began in October 2020 and ended three weeks later to reduce maturation effects in participant responses. The risk of self-selection bias was present but tempered by the intentional targeting of a specified group that did not differ in study experiences. Data were cleaned to remove extreme outliers that could cause platykurtic distributions. Resulting data analyses provided a strong warrant to the fact that bias either did not skew the data or the DIY e-juice community has an innate degree of bias that is then accurately represented.

Results

Prolific preemptively gathered data regarding participant age (100% 18 or 19 years old), employment status (55% part-time or unemployed seeking a job), sex (74% male), and student status (86% current student). Nationality varied with representation from Poland (62%), United Kingdom (11%), United States (7%), and 18 additional countries (3% or less). Participants provided data regarding ethnicity (80% non-Hispanic), race (85% White), and highest degree earned (78% high school diploma, GED, or less). Regarding smoking history, 91% had smoked a puff of a cigarette, 85% had smoked marijuana, and 44% had vaped marijuana. Over the last 30 days, the average participant vaped nicotine on 16 days (SD = 12.05). Most participants reported inhaling when they hit a device (84%), and typically hitting a device for three seconds or less (88%). Vape-related preferences included variable voltage devices (59%), medium or large size devices (67%), fruit flavored liquid (58%), and mesh coils (70%) that were purchased instead of made (78%). Independent samples *t* test was used to explore other demographic factors that could be associated with a higher intention to mix DIY e-juice, finding no differences in smoking history, country of origin, marijuana use, engaging in vape tricks, inhale time, hit length, mod size, coil type, flavor preference, or ethnicity. However, participants who preferred a variable voltage device were more likely to intend to mix DIY e-juice than those who preferred a regulated voltage device ($t[201] = 2.35$, $P = 0.01$, Cohen's d = .33). Similarly, males were more likely to intend to mix DIY e-juice than females ($t[197] = 2.42$, $P < 0.01$, Cohen's d = 0.39).

Path analysis modeling was used to examine the extent to which the TPB would, first, predict behavioral intention to vape and then, second, predict behavioral intention to mix DIY e-juice. The TPB correlation matrix for both behaviors is presented in Table 1. With the exception of mixing-related perceived norms on mixing-related intentions, all paths in Figure 1 were significant. However, following Kline,[31] initial model fit was not supported, suggesting that the data did not fit the model well ($\chi^2[19] = 116.79$, $P < 0.001$; RMSEA = 0.160 [CI: 0.133, 0.188], $P < 0.001$; GFI = 0.877; CFI = 0.550; SRMR = 0.123). As this model was a starting point for testing a multiple behavior approach of the TPB, theoretical relationships were reexamined to explore the possibility of rival models, which allow researchers to explore other theoretical explanations. Rival models were tested using the same TPB constructs from Figure 1. Through further reflection, three rival models were tested with the last model being a good fit for the data. The arguments for the changes that led to the final model follow.

The first rival model included a direct path from vaping-related intention to DIY mixing-related intention (see Figure 2). Given this first multiple behavior test of the TPB, this path would capture the influential relationship between the two behaviors. Although the fit indices suggested that the data fit slightly better, they were still far from supporting a good fit ($\chi^2[18] = 112.88$, $P < 0.001$; RMSEA = 0.162 [CI: 0.134, 0.191], $P < 0.001$; GFI = 0.881; CFI = 0.563; SRMR = 0.121).

For the second rival model (see Figure 2), because both vaping and mixing have been found to be highly influenced by social factors, it stands to reason that users who have stronger social normative perceptions would have more positive attitudes toward the behavior. Thus, paths from perceived norms to attitude were added for each behavior. Again, the fit indices improved with two indices suggesting good data fit (GFI = 0.946; SRMR = 0.078), but three indices indicated the data still did not fit well ($\chi^2[16] = 50.02$, $P < 0.001$; RMSEA = 0.103

Table 1. Correlation matrix among TPB constructs across vaping- and mixing-related behaviors

Variable	1	2	3	4	5	6	7	8
1. VAtt	1							
2. VNorm	0.318***	1						
3. VBC	0.024	-0.019	1					
4. VBI	0.289***	0.326***	-0.284***	1				
5. Matt	0.356***	0.288***	0.005	0.407***	1			
6. MNorm	0.124*	0.337***	-0.023	0.230***	0.476***	1		
7. MBC	-0.043	0.112	-0.095	0.144*	0.054	-0.091	1	
8. MBI	0.135*	0.029	0.043	0.219**	0.283***	0.242***	-0.143*	1

Notes: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; 'V' in variable name refers to vaping-related and 'M' refers to mixing-related.

[CI: 0.071, 0.135], $P < 0.01$; CFI = 0.843).

Finally, the last rival model considered that the TPB constructs regarding the behavior of vaping (e.g., perceived attitudes toward vaping) would likely be related to the parallel construct regarding the behavior of mixing (e.g., perceived attitudes toward mixing) in that more positive TPB perceptions on vaping would be related to more positive perceptions toward mixing DIY e-juice. Following these three theoretically grounded arguments, the data fit the third rival model well (see Figure 3). More specifically, fit indices supported reasonable model fit (RMSEA [CI: 0.001, 0.083] = 0.037, $P = 0.622$) and acceptable fit compared to a worst fitting (CFI = 0.983) or no model (GFI = 0.980). In addition, the covariance residuals were as expected (SRMR = 0.039). Similarly, the model was not statistically different from a best possible fitting model ($\chi^2[13] = 16.61$, $P = 0.218$). Thus, the data fit this model well.

Discussion

This study was the first theoretical exploration of a multiple behavior test of the TPB and of the behavioral performance of DIY e-juice mixing among young adult international ENDS users. Data showed that the primary constructs of the TPB can predict and explain DIY e-juice mixing behaviors, which are informed by the TPB constructs regarding the behavior of vaping. The applicability of a rival model's superior explanatory power is a crucial implication of this study. Public health interventions rely on theoretical approaches with external reliability in order to craft successful and enduring interventions. Decades of past TPB research has helped tobacco prevention scholars better understand the underlying processes surrounding tobacco prevention-related behaviors. This study contributes to that scholarly understanding in keyways.

First, the initial model tested a two-step, multiple behavior approach of the TPB, with a TPB model regarding vaping predicting a TPB model regarding mixing DIY e-juice. This model stems from an initial argument[20,21] that attitudes, subjective norms, and behavioral control are the gatekeepers of influence on behavioral intention. Although the TPB did not outline expectations for a multiple behavior approach, the primary assumptions held to some extent. For the first behavior (i.e., vaping), the constructs of attitudes, subjective norms, and behavioral control were predictive of behavioral intention as expected. However, when the second behavior (i.e., mixing DIY e-juice) was included, additional paths formed. New paths revealed predictive

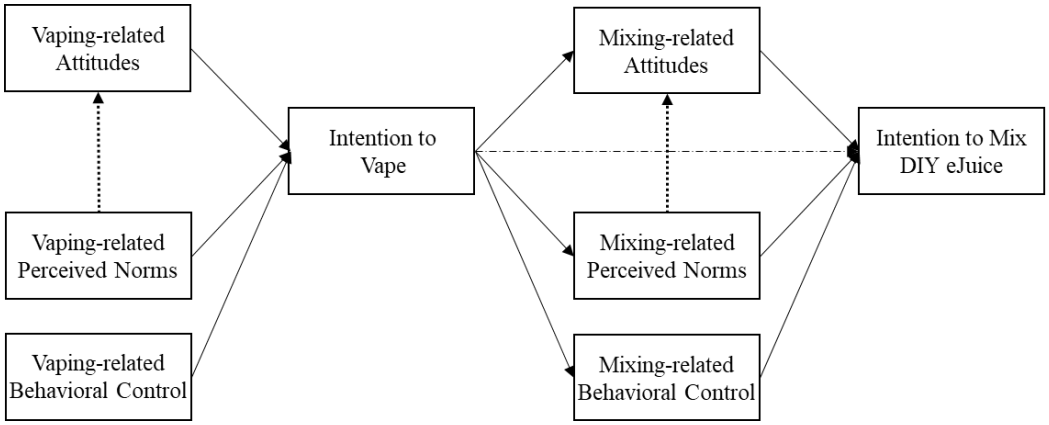

Figure 2. Rival models 1 & 2: theory of planned behavior-based predictions of intention to mix DIY e-juice. Note: Solid lines from proposed model; light dash line added for rival model 1; dark square line added for rival model 2

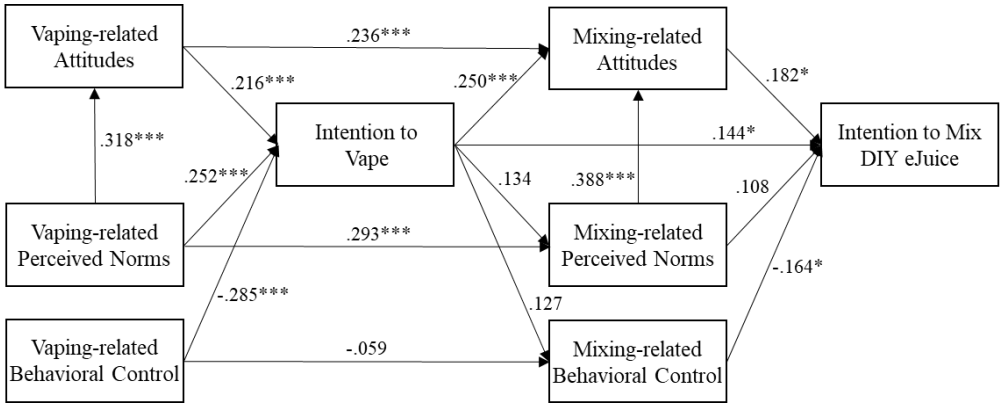

Figure 3. Final model: theory of planned behavior-inspired predictions of intention to mix DIY. e-juice. *$P < 0.05$, ***$P < 0.001$

relationships from the parallel constructs of the first and second behavior (e.g., vaping-related attitudes predicted mixing-related attitudes) and a direct relationship from intention to perform the first behavior to intention to perform the second. These paths were statistically significant for all except perceived behavioral control. This is not entirely surprising: the ability to purchase and use an ENDS device requires substantially less effort than the ability to learn, purchase, mix, and try e-juice. Although this path was not a statistically significant predictor, it was important enough that if removed, the data no longer fit the model well. For embedded behaviors, one's ability to perform the first behavior appears to be independent of one's ability to perform the second.

Second, new relationships between attitudes and perceived norms emerged. The influence of subjective norms on attitude was imperative to the data fitting a model. Although TPB studies typically find attitudes and subjective norms to be highly correlated,[32-34] the findings from this study suggest that their direct relationship is likely a central part of the underlying behavioral processes so much so that intention to perform the embedded behavior was not predicted by perceived norms of that behavior. Instead, an indirect relationship emerged wherein norms of the second behavior predicted attitudes of the second behavior which predicted behavioral intention. The role of perceived norms in the TPB has been the most heavily discussed aspect of the model,[25] and likely to be an evolving construct as social normative engagement changes. For instance, in a world where normative influences are synonymous with our online experiences, it is plausible that normative formation no longer occurs outside of attitude formation as an independent factor, but instead, as predictive of attitude formation itself. As people continue to create echo-chambers in their information sources, separating normative influence from attitude formation could be theoretically superficial.

Finally, the findings of this study suggest that ENDS users with pro-vaping attitudes, strong normative influences, and low perceived control hold a higher intention to vape. Not only will their intention to vape be predictive of mixing in and of itself, those with the strongest attitudes toward mixing (which is predicted by those with the highest perceived normative perception of mixing) and lowest degree of perceived control toward mixing will be the most likely ENDS users to mix DIY e-juice. In addition, male ENDS users and users of variable voltage devices hold a higher intention to mix DIY e-juice. The device preference is not surprising given that most devices with regulated voltage, such as Juul pods, come with pre-filled liquid that are not easily refilled. [2] It is plausible that those with an intention to mix specifically seek a variable voltage device to add their own e-juice mix. However, a counter perspective is that the variable voltage device is not initially selected for mixing purposes, but that mixing becomes a curiosity due to the opportunity. Thus, variable voltage devices could be perpetuating the curiosity of DIY e-juice mixing.

Knowing the specific type of ENDS users most likely to mix DIY e-juice will help tobacco prevention and control advocates more efficiently reach this particular group, if needed. For instance, when the European Union revised their Tobacco Products Directive strengthening regulations on the limits of nicotine concentration, studies found the counter effect was an increase in DIY e-juice mixing as a means to bypass regulations.[35] If the FDA or other national agencies were to tighten regulations surrounding e-juice, the same outcome could happen in other countries. Data from this study suggest that men who are the most pro-vaping, with strong vaping communities, and preferring variable voltage devices might be the most likely to attempt to stockpile pre-regulation and, therefore, be in the most need of public health and health communication messaging surrounding the health-related rationale for the regulation and the importance of complying with the change in policy. In addition, the new theoretical paths suggest a normative influence on perceived attitudes, and a perceived capability of performing the embedded behavior (i.e., mixing) to be independent from that of the foundational behavior (i.e., vaping). Health promotion efforts should leverage these findings in DIY e-juice awareness and prevention messaging and in tobacco regulatory decisions that directly impact young adult ENDS users. This is an especially timely consideration in light of the interplay of three ongoing epidemics: vaping, opioid use, and COVID-19.[36]

The takeaways of this study are bolstered by promising signals of strong external validity. Little research has discussed DIY e-juice, yet the results of this study, despite having significant variation in population, setting, timing, and recruitment method, mirror the limited pre-existing research. Further, the contributions made to TPB improve upon a model that has consistently been utilized and validated for decades. Coupled with the lack of statistical differences emerging between countries and the confirmation that previously known modifiers, such as gender and education, remain, the data reported here support the outlined implications.

There are some limitations that should be acknowledged. First, although this study was conducted on an international sample, within-nation representation is small with a majority of perspectives from Poland. Second, the majority of participants reported consuming marijuana, a substance with stricter regulations than nicotine. Questions in the study were not intended to explore cannabidiol or THC-related e-juice mixing. Potential bias can always emerge when illicit substances

are investigated. Participants may choose to up-play or down-play certain beliefs in order to craft a particular image. While this may change the direction or magnitude of some results, understanding community representations of the DIY e-juice attitudes, behaviors, and intentions is still promising and productive for addiction scholars. Future research should continue to explore multiple behavior approaches as well as the complex processes surrounding DIY e-juice mixing. As research continues to find discrepancies in mixing concentration labels, dissemination efforts are needed to effectively inform ENDS users who mix DIY e-juice of the known risks. Finally, regulatory science investigations should consider the extent to which federally regulating DIY e-juice mixing would be effective in reducing ENDS use.

Conclusion

As the trend of DIY e-juice mixing continues to grow, additional research employing behavior change theories is needed to examine the behavioral processes surrounding DIY e-juice mixing. This study was the first theoretical exploration of a multiple behavior test of the TPB and of the behavioral performance of DIY e-juice mixing among ENDS users. Data showed that the primary constructs of the TPB can predict and explain DIY e-juice mixing behaviors, which are informed by the TPB constructs regarding the behavior of vaping. These findings contribute to the scholarly understanding of the behavior of DIY e-juice mixing among young adult international users.

Authors' Contribution

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Competing Interests

There are no conflicts of interest to report.

Data Availability Statement

The data underlying this article will be shared on reasonable request to the corresponding author.

Ethical Approval

The study protocol was approved by the Institutional Review Board at San Diego State University (approval number HS-2020-0187).

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