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Measuring E-cigarette Dependence: Initial Guidance

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Abstract

E-cigarette use rates are increasing among youth and adults, despite limited knowledge about the safety, risks, and potential for this product in substituting for or reducing other tobacco use. Understanding how to characterize and assess e-cigarette dependence will be important for evaluating the public health impact of e-cigarettes and considering prevention and intervention strategies. To provide an initial review of constructs to consider when assessing e-cigarette dependence, a content expert group within the Tobacco Center for Regulatory Science (TCORS) Measurement Workgroup engaged in a review of published manuscripts and 12 tobacco dependence measures, followed by review of suggested dependence domains by a 10-person external subject-matter expert panel. The final domains selected to be considered in the development of a measure of e-cigarette dependence included: 1) Quantity and frequency of use, 2) Tolerance, 3) Perceived benefits, 4) Withdrawal symptoms, 5) Craving/urge to use, 6) Use despite harm, 7) Impaired control, 8) Automaticity, 9) Preferred over competing rewards, and 10) Sensory dependence. Similarities and differences in potential features of e-cigarette dependence compared with dependence on other tobacco products is discussed. Future work will evaluate these dependence items and constructs in a sample of e-cigarette users with a goal of developing a valid, brief, standardized measure of e-cigarette dependence.

Keywords

e-cigarette; dependence; electronic cigarette; tobacco

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1 Introduction

Electronic cigarettes (e-cigarettes) are battery-operated devices used to vaporize solutions that may contain nicotine and flavors[1]. E-cigarette devices vary widely; they may be disposable or rechargeable; include manual buttons to change heating, voltage, and wattage; and contain e-liquids which vary in their specific constituents, nicotine concentrations, and flavors. E-cigarette use rates have increased significantly across the globe[2,3], despite limited evidence regarding the health effects or the potential for this product to replace or reduce other tobacco use. To address these gaps in knowledge, the Food and Drug Administration Center for Tobacco Products has outlined research on addiction as a priority area, including studies of how tobacco product characteristics (such as flavors or product design) impact dependence. To further these research objectives, reliable and valid means of assessing dependence to e-cigarettes and other new tobacco products are needed.

1.1 Conceptualizing Dependence Among E-Cigarette Users

Given that nicotine itself is a primary reinforcer that can lead to dependence when used repeatedly[4–6], it is likely that some aspects of dependence will overlap between e-cigarettes containing nicotine and other tobacco products. However, characteristics of e-cigarette products could contribute to dependence in unique ways. For example, characteristics of the product that are consistently paired with nicotine can acquire reinforcing properties through associative learning[7], and the cues associated with e-cigarette use are unique compared to traditional cigarettes (e.g., e-liquid flavors, vape clouds, contexts where e-cigarettes are used, and device type including the ability to customize features). Thus, the goal of the current paper is to review features of e-cigarettes to consider in assessing e-cigarette dependence and to provide guidance on dependence constructs that could be considered when developing such a measure.

1.2 The Present Study

The Tobacco Center for Regulatory Science (TCORS) Measurement Workgroup was convened to consider aspects to include in a measure of e-cigarette dependence. To date, only one e-cigarette dependence measure has been developed; the Penn State Electronic Cigarette Dependence Index assesses frequency, craving, and withdrawal[8]. The workgroup reviewed this index as well as several measures of tobacco dependence, with the goal of assembling multiple aspects of dependence, such as those related to the primary reinforcement process of nicotine exposure (e.g., withdrawal, tolerance, craving) as well as those related to cue-driven or habitual processes driven by associative learning (e.g., automaticity, perceived benefits of use, preference over competing rewards).

2 Methods

2.1 Subject Matter Expert Discussions

In June 2015, six subject matter experts (Grana, Fishbein, Foulds, Krishnan-Sarin, Roditis, Sussman) conducted a literature search in Google Scholar using the key words “nicotine dependence” and “reviews” and reviewed the first 200 pages to identify existing nicotine and

tobacco dependence measures. The workgroup selected specific measures that would be applicable to the assessment of e-cigarette dependence (Table 1). These measures were used to identify potential dependence constructs that were sent to an external expert panel for review.

2.2 External Expert Panel Review

Potential constructs with sample items (see Appendix A) were sent to 10 external subject matter experts who were told that the goal was to compile a comprehensive list of constructs to be considered in the creation of an e-cigarette dependence measure. Experts provided written feedback on whether the constructs and definitions were 1) understandable, 2) necessary for the creation of comprehensive dependence measures, and 3) appropriate in their specificity. Reviewers could also provide general feedback about the constructs and whether anything should be kept, deleted, modified, or merged with another construct. The list of constructs was further modified based on responses from 7 of the 10 reviewers; the other 3 reviewers verbally indicated that they did not have any changes. The final list of constructs and sample items identified are described in Table 2. Two constructs from the original list (“emotional reactions to encourage use” and “affiliative attachment”) were reclassified (“perceived benefits” and “preference over competing rewards”) as experts believed these terms more accurately described dependence processes. Additionally, one construct (“social goads”) was replaced (“use despite harm”) based on feedback that the latter was more diagnostic and central to dependence.

3 Results and Discussion: Final E-cigarette Dependence Constructs to Consider

3.1 Quantity and frequency of use

While patterns of e-cigarette use are likely important to the assessment of e-cigarette dependence, quantifying e-cigarette use behaviors is not easy, especially given the wide variability in terminology, device type (e.g., “e-cigarettes”, “e-hookahs”, “vape pens”[1]), nicotine concentrations, and puffing/vaping behaviors. Still it was the opinion of the subject matter experts that heaviness of use is an important measure to obtain, either as part of an e-cigarette dependence measure or separately alongside smoking history (please see guidance about measuring use provided by Weaver and colleagues, this volume).

3.2 Tolerance

Tolerance is a common feature of dependence, representing a markedly diminished effect of the product over time or needing increased amounts of the product to achieve the same effect[6]. However, e-cigarette tolerance may not necessarily be as straightforward as measuring changes in quantity or frequency of use. E-cigarette products are highly variable and many are customizable, including the ability to change device and e-liquid features such as the device shape, size, temperature, nicotine concentration, vapor flow, and flavor, which can impact the delivery of nicotine and other constituents. For example, larger capacity batteries that heat the e-liquid to higher temperatures produce more aerosol per puff and supply more nicotine and other constituents[9]. Therefore, evidence of tolerance could be

reflected not only by the person using e-cigarettes more frequently, but by the person increasing nicotine concentration, changing device characteristics or e-liquid constituents to get the desired effect.

3.3 Perceived Benefits

As described earlier, e-cigarettes deliver nicotine and flavors and a variety of other constituents. Nicotine is not only a primary reinforcer, but it has properties that enhance the reinforcing effects of other rewarding stimuli[7]. Thus, the perceived benefits of e-cigarette use (e.g., helps you feel better, makes experiences more enjoyable) may be related both to the direct pharmacological effects of nicotine, similar to other tobacco products, and also to the unique product-related characteristics of e-cigarettes (e.g., flavored e-liquids) through associative learning processes.

3.4 Withdrawal Symptoms

Withdrawal symptoms (e.g., changes in affect, restlessness, difficulty concentrating) are experienced when a user stops using the addictive substance, which then promote continued use to alleviate these symptoms[10]. Pharmacological withdrawal from nicotine is likely similar across tobacco products. However, the degree of withdrawal from e-cigarettes may vary, given differences in nicotine delivery and more continuous use patterns (e.g., repeated bouts of puffing throughout the day). Current e-cigarette devices can yield peak levels of nicotine similar to cigarettes, but these levels may not be achieved as rapidly[11]. Prior studies have found that exclusive e-cigarette users experience nicotine withdrawal symptoms, albeit at lower rates than cigarette smokers[8,12].

3.5 Craving/urges to use

Craving, or urge to use, is a key symptom experienced both during abstinence and while continuing to use the substance that motivates sustained use[6,13]. Craving is known to persist for a long time after abstinence is achieved and is an established predictor of lapse or relapse to use of a variety of addictive substances[5]. Craving for e-cigarettes likely has commonalities with craving for cigarettes, but may be linked to unique cues associated with e-cigarette use, such as vape shops, vape clouds, and e-cigarette paraphernalia.

3.6 Use Despite Harm

Continued use despite harm reflects persistent use despite negative physical, psychological, or social consequences[6]. E-cigarettes may be perceived as safer and more socially acceptable than conventional tobacco products, so fewer consequences may be endorsed. Although the long-term health effects of e-cigarette use are not yet known for these relatively new products, current evidence suggests the potential for negative cardiovascular and pulmonary effects of e-cigarettes[14–16].

3.7 Impaired Control

Impaired control is defined as a breakdown of an intention to limit consumption[6]. Impaired control may be an early nicotine dependence symptom,[17] reflecting a loss of autonomy over use related to neuropharmacological, psychological, or behavioral mechanisms[18]. For

example, impaired control over e-cigarette use may be related to difficulty reducing or limiting use in terms of quantity, frequency, as well as nicotine level.

3.8 Automaticity

Automaticity describes a behavior that has an automatic or habitual response pattern that is usually acquired through learning and repetition, such as repeated tobacco use[19,20]. For example, individuals may find themselves reaching for their e-cigarette or vaping without thinking about it. Other behaviors related to e-cigarette use, such as dripping[21,22] and vape tricks[23,24], may also become automatic, habitual processes.

3.9 Preferred over competing rewards

This construct is the tendency to forgo other rewards or activities to use the substance and is an important aspect of dependence in behavioral economics models of addiction[25,26]. For example, an individual may prefer tobacco use over other activities or rewards or not engage in certain activities where use is not permitted, although e-cigarette use may not be restricted in public places in the same way as other tobacco products[27].

3.10 Sensory Dependence

This construct relates to the positive consequences associated with specific taste and sensory stimuli when using the addictive substance[19], which may motivate continued use or a return to use following abstinence. Compared to use of conventional tobacco products, e-cigarette use may be associated with unique sensory experiences related to characteristics of the device or e-liquid constituents (including over 7000 e-liquid flavors[28]) which can impact the subjective experience of e-cigarettes. E-cigarette users note many positive sensory aspects of e-cigarette use, including enjoying flavors, a “throat hit”, and the emission of thick vapor clouds that can be used for vape tricks[23,24,29] which all may serve to reinforce e-cigarette use behavior.

4 Conclusions

The purpose of this manuscript is to provide guidance on domains or constructs to consider when developing a measure of e-cigarette dependence. Twelve existing measures of dependence were examined in detail and 10 dependence domains were established, plausibly applicable to e-cigarettes. Several constructs are likely common between cigarette and e-cigarette dependence, such as craving, withdrawal, and impaired control, suggesting that existing measures of nicotine dependence could be adapted to measure these constructs in e-cigarette users. One such measure is the Patient Reported Outcomes Measurement Information System (PROMIS) Nicotine Dependence Item Bank[30–32]. Of note, the 22-item version of the PROMIS incorporates most of the domains identified by the working group, with the exceptions of tolerance, perceived benefits, and sensory dependence. However, our review also suggests that several factors unique to e-cigarette products, such as the ability to modify the experience through device characteristics and the variety of e-liquids, should be considered when assessing e-cigarette dependence, and as a result, existing nicotine dependence measures may be inadequate templates for measuring some domains of e-cigarette dependence, such as sensory dependence. Interestingly, one prior study observed

that although dependence scores were positively related to e-liquid nicotine concentration, the zero nicotine users also showed signs of dependence[8]. Thus, even without nicotine, e-cigarette users may develop a strong affiliative attachment to e-cigarettes, and it will be important to consider the unique sensory and behavioral cues for e-cigarette use when assessing e-cigarette dependence.

The next steps for the TCORS dependence workgroup will include examining the use and validity of the dependence constructs described above by evaluating responses among current e-cigarette users on items from existing nicotine dependence measures that have been adapted for e-cigarettes as well as expanded items reflecting unique aspects of e-cigarette use. Following recommendations for an ideal tobacco dependence assessment[33], a primary goal will be to develop a measure assessing e-cigarette dependence with 1) clear, straightforward items and scoring such that the measure can be adapted to various e-cigarette devices and brief enough for possible use in clinical settings, 2) constructs and domains that are theoretically and empirically central to dependence that can be generalized to e-cigarette use, and with 3) sound psychometric properties (e.g., construct, convergent, and discriminant validity compared with biochemical and other standard assessment measures). Additionally, e-cigarette dependence assessment may differ between youth and adults, and this will be an important area for future research. Ultimately, identifying the optimal ways of characterizing and assessing e-cigarette dependence will be important for advancing our understanding of the public health impact of e-cigarettes and the development of prevention and intervention strategies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- Understanding how to assess e-cigarette dependence is important for public health
- An expert group reviewed domains to consider when assessing e-cigarette dependence
- External subject-matter experts provided feedback on potential dependence domains
- 10 final domains are reviewed as guidelines for assessing e-cigarette dependence

Table 1

Tobacco Dependence Measures Reviewed

Measure	Description
Cigarette Dependence Scale (CDS)[34]	12 items, assesses a total dependence score (e.g., "For you, quitting smoking for good would be" rated from 1=very easy to 5=impossible)
Dimensions of Tobacco Dependence Scale (DTDS)[35]	54 items, 4 factors, assesses tobacco dependence in adolescents: social reinforcement, emotional reinforcement, sensory reinforcement, physical reinforcement
Fagerstrom Test for Nicotine Dependence[36]	6 items, intending to assess physical dependence, rated 0–2=very low dependence, 3–4=low dependence, 5=medium, 6–7=high dependence, 8–10=very high dependence
Hooked on Nicotine Checklist (HONC)[18,37]	10 items, a proxy for the ICD-10 criteria of tobacco dependence, intended to assess the development of dependence in young people, assessing early symptoms of dependence and the loss of autonomy over tobacco use (e.g., "Do you smoke now because it is really hard to quit?")
Minnesota Nicotine Withdrawal Scale[38,39]	8 items, assesses a single factor of nicotine dependence based on DSM-IV withdrawal criteria (i.e., craving, irritability, anxiety, difficulty concentrating, restlessness, increased appetite/weight gain, depressed or sad mood, insomnia)
Nicotine Dependence Syndrome Scale (NDSS)[40]	19 items, assesses a total dependence score and 5 factors: smoking drive (i.e., strong urges), behavioral priority (i.e., smoking preferred over other competing reinforcers), tolerance, continuity (i.e., smoking with little interruption), and stereotypy (i.e., smoking at a constant rate uninfluenced by contextual stimuli)
Patient-Reported Outcomes Measurement Information System (PROMIS)[30,31]	32 items, assesses a unidimensional set of nicotine dependence items for daily and non-daily smokers with items derived from validated existing measures and focus group testing (Edelen, Tucker, Shadel, Stucky, & Cai, 2012); 22 items are common across daily and non-daily smokers, with 5 unique to daily or nondaily smokers
Penn State Electronic Cigarette Dependence Index[8]	10 items, questions can be modified to assess cigarette or e-cigarette dependence (e.g., "Is it hard to keep from using an electronic cigarette in places where you are not supposed to?")
The Population Assessment of Tobacco and Health (PATH) Study[41]	20 items, assesses craving, tolerance, loss of control, withdrawal
Tobacco Craving Questionnaire[42]	17 items, assesses 4 specific constructs: emotionality (i.e., anticipated relief from negative mood or withdrawal), expectancy (i.e., anticipated positive outcomes of smoking), compulsivity (i.e., inability to control tobacco use), purposefulness (i.e., intention and planning to smoke for positive outcomes)
Tobacco Use Disorder (DSM-5, Appendix B)[13]	11 items, used as diagnostic criteria to assess severity of tobacco use disorder, at least 2 symptoms present in the last year indicates tobacco use disorder, rated 2–3 symptoms=mild, 4–5=moderate, 6+=severe
Wisconsin Inventory of Smoking Dependence Motives (WISDM)[19]	68 items, assesses 13 factors: affiliative attachment, automaticity, behavioral choice/ melioration, cognitive enhancement, loss of control, craving, cue exposure/associative processes, negative reinforcement, positive reinforcement, social/environmental goads, taste/ sensory properties, tolerance, weight control

Table 2

Potential E-Cigarette Dependence Constructs and Example Items

Construct	Example Items
Quantity and Frequency of Use	• How many puffs, on average, do you take on your e-cigarette on a typical day? • How many days per week do you vape? • What dose of nicotine do you normally use? • How many milliliters of liquid do you use per day?
Tolerance	• I feel like I need to use my e-cigarette more to get the desired effect • Compared to when I first started vaping, I feel like I need to vape more to get the desired effect • Compared to when I first started vaping, I changed how I use e-cigarettes (e.g., increase nicotine concentration, change devices) to get the desired effect
Perceived Benefits	• Vaping helps me feel better if I have been feeling down • Even when I feel good, vaping helps me feel better • Vaping helps me think better
Withdrawal Symptoms	• After not vaping for a while, I need to vape to avoid any discomfort • When I have not used an e-cigarette for a while, or tried to stop vaping, I feel more nervous/restless/anxious because I could not vape • When I go too long without vaping, I feel impatient or irritable
Craving/Urges to Use	• When I have not vaped for a while, the craving gets intolerable • I crave e-cigarettes at certain times of the day • It is hard to ignore urges to vape
Use Despite Harm	• My e-cigarette use has caused problems • I continue to use despite disapproval or conflict with my friends or family • I experience negative physical or psychological consequences from vaping
Impaired Control	• I tried to stop vaping but couldn't • I feel like e-cigarettes rule my life • I feel like my vaping is out of control
Automaticity	• I find myself vaping without deciding to • I find that sometimes I am not aware that I am vaping • I find myself reaching for e-cigarettes without thinking about it
Preferred Over Competing Rewards	• I would drop everything to go out and buy e-cigarettes • I would not do things or go places (movies, long plane flight, social gatherings) if I am not allowed to vape
Sensory Dependence	• The flavor of an is e-cigarette pleasing • I enjoy the feel of inhaling vapor into my mouth • I love the smell of e-cigarettes • I like the feeling of creating vapor clouds

Note: Items are presented as examples representing each dependence construct. Further psychometric testing of items, including item structure and scoring, are needed to develop a validated measure of e-cigarette dependence.