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I wake up and hit the JUUL: Analyzing Twitter for JUUL Nicotine Effects and Dependence

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Abstract

Background: JUUL—a novel electronic nicotine delivery system (ENDS)—comprises most of the ENDS market share. Additionally, JUUL has a high nicotine content and utilizes a patented nicotine salt formulation aimed to speed absorption. Many JUUL users are not aware of the nicotine content and therefore may not be expecting acute nicotine effects or potential for dependence. This study sought to analyze Twitter messages ("tweets") regarding nicotine, symptoms of dependence, and withdrawal related to JUUL use.

Methods: Data were collected from Twitter's Filtered Streams interface 4/11–6/16/2018 by retrieving tweets matching the terms "juul," "juuls," and "juuling" that also used words consistent with nicotine effects, symptoms of dependence, and withdrawal. A random 5% subsample (n=1986) was coded by 2 independent coders. Cohen's κ for inter-rater reliability ranged 0.62–1.00 for all coded variables. Tweets were assessed using a qualitative content analysis approach.

Results: A total of 335 tweets mentioned dependence-related themes, including use upon waking and compulsion to use. A total of 189 tweets mentioned themes related to nicotine, with almost 15% of these tweets describing physical effects. Additionally, 42 tweets mentioned themes related to quitting JUUL and/or withdrawal from JUUL.

Discussion: This qualitative analysis suggests that users of JUUL are experiencing symptoms of nicotine exposure and dependence. Considering the high nicotine content of JUUL and the rising popularity among young people, more research around initiation of and dependence on JUUL, as well as the impact of recent FDA policy changes, should be conducted.

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Contributors

Author JS designed the project, oversaw data collection and coding, and wrote the initial draft of the manuscript. Authors JS, JC and KHC assisted with data collection and coding and substantially edited sections of the initial draft of the manuscript. Authors JS, AS, and JC conducted and are responsible for the data analysis. Author EB conducted data coding and wrote sections of the initial draft of the manuscript. Authors AS, AEJ and BP wrote sections of the initial draft, provided substantial edits to the final manuscript, and provided project oversight. All authors approved the final manuscript as submitted.

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Keywords

JUUL; Nicotine; Dependence; Withdrawal; Twitter

1. Introduction

The use of electronic nicotine delivery systems (ENDS) rose sharply among young people in the US between 2017 and 2018, with a 78% increase in current use among high school students and a 47% increase in use among middle school students (U.S. Food and Drug Administration, 2018). Additionally, approximately 10% of young adults report current (i.e., past 30 days) ENDS use (J. L. King et al., 2018). Preliminary evidence suggests that initiation of ENDS use at a young age is associated with nicotine dependence (Vogel et al., 2018), and that use of ENDS is associated with initiation of cigarette smoking among both youth and adults (Barrington-Trimis et al., 2016; Primack et al., 2018, 2015). One such ENDS product is JUUL—a small, sleek device that can be charged via USB drive (JUUL Labs Inc., 2018a). The popularity of JUUL has risen sharply since its introduction to the market in 2015 (B. B. King et al., 2018), and it now composes almost three-quarters of the ENDS market share (LaVito, 2018a).

One particularly concerning aspect of JUUL is its nicotine concentration, which is markedly higher than most ENDS available on the market before JUUL's introduction in 2015 (Jackler and Ramamurthi, 2019). Until August 2018, all JUUL pods—the multi-use cartridge that holds the flavored e-liquid—contained approximately 40mg of nicotine per pod, or 59mg/mL (JUUL Labs Inc., 2018b; LaVito, 2018b). A lower nicotine content (approximately 23mg per pod, or 35mg/mL) became available for most flavors in August 2018 (JUUL Labs Inc., 2018b). Thus, at the time of this study, the amount of nicotine in JUUL pods was greater than or approaching the nicotine content of most other ENDS, which typically range in nicotine content from 0mg/mL to 30mg/mL (Marsot and Simon, 2016; Morean et al., 2016). Additionally, JUUL utilizes a patented nicotine salts formula, which "provide[s] a general satisfaction effect consistent with an efficient transfer of nicotine to the lungs of an individual and a rapid rise of nicotine absorption in the plasma" (Bowen and Xing, 2014). Therefore, an individual using JUUL is likely exposed to a high amount of nicotine. Indeed, a study of US youth found that those who reported use of vape pod ("pod") systems—the majority of whom used JUUL—had urinary cotinine concentrations double that of what is found among users of non-pod ENDS (Goniewicz et al., 2018). Finally, it is unclear whether most individuals understand the nicotine content of ENDS products, including JUUL (Rohde et al., 2018; Willett et al., 2019). Only 37% of past-30 day JUUL users correctly identified that the product contains nicotine (Willett et al., 2019), suggesting that most users do not expect to experience acute nicotine effects or symptoms of dependence.

To our knowledge, there have been no studies on self-reported symptoms of dependence on JUUL or the physical effects usually associated with nicotine exposure. One potentially valuable data source is Twitter, which is a social media platform that is used by approximately 25% of US adults and 32% of US teens, of which almost half report using it

at least once per day (Anderson and Jiang, 2018; Smith and Anderson, 2018). Additionally, a recent study estimated that approximately 45% of individuals who followed the official @JUULvapor account in April 2018 were ages 13–17, while only 20% were ages 21 or older, suggesting that many JUUL followers are not of legal age to use the product, yet are still being exposed to related messaging (Kim et al., 2019). Twitter also has the advantage of allowing more real-time surveillance and analysis when compared to traditional, time-lagged data collection and reporting methods (Broniatowski et al., 2013). Health researchers have begun to develop standards for methodologies and reporting when using Twitter to explore myriad health topics (Colditz et al., 2018; Lienemann et al., 2017), as research suggests that anonymity allows individuals to be more candid about health topics (Berry et al., 2017; Fear et al., 2012; Sinnenberg et al., 2017). Discussions around JUUL on Twitter have been examined previously. A recent study found that Twitter discussions regarding JUUL frequently involve communication with others (or "tagging" another Twitter user when discussing JUUL) and discussion of use of JUUL in schools and on college campuses (Allem et al., 2018). Another recent study found that some JUUL users used "nicotine-dependence terms" on Twitter (Kavuluru et al., 2019). However, this study did not conduct an in-depth examination of these terms.

Therefore, the purpose of this study was to systematically examine Tweets mentioning JUUL and identify themes related to symptoms of dependence, withdrawal, and nicotine exposure. This process serves to contextualize the social conversation around JUUL nicotine effects and dependence-related terminology as demonstrated through a popular public social media platform.

2. Methods

2.1. Study Procedures

This study was approved by the University of Pittsburgh IRB. Data were collected using the publicly available "RITHM" software (Colditz et al., 2018) to retrieve data directly from Twitter's Filtered Streams interface for 4/11/2018–6/16/2018. Search filters were set to retrieve all available tweets matching the terms "juul," "juuls," and "juuling" (including these terms used as hashtags). Using this approach, we are able to retrieve up to 100% of matching tweets that are publicly available, originating from Twitter profiles that are not set as private (Colditz et al., 2018). This process resulted in 644,285 matched tweets, from which 485,352 re-tweets were excluded, leaving 158,933 original tweets. In order to narrow the focus to the constructs of primary interest (i.e., nicotine effects and dependence), the research team met and pilot tested several keywords to narrow the scope of tweet content. Based on face validity and preliminary search performance, we selected final set of 20 keyword stems (*wake, woke, morning*, buzz*, dizzy, crav*, want*, need*, buy, bought, get, got, take, took, steal, stole, borrow*, addict*, withdraw*, quit**). Keyword stems matched with a variety of suffixes (i.e., *crav** may include terms such as *crave, craving, craved*, etc.). This process resulted in a matched set of 41,205 original tweets. This sample was further reduced to a random 5% subsample (n=2,060) for feasibility of human qualitative coding and while still demonstrating the generalizability of the subsample within the context of the full dataset; this approach has been used in similar examinations of Twitter data (Colditz et

al., 2019, 2018; Martinez et al., 2018). Experienced human coders used spreadsheets which included tweet text and a link to the online version for each tweet, with the option to use one or both of these representations to determine tweet characteristics. In order to assess data retrieval specificity (precision), all tweets were initially coded for relevance (i.e., JUUL-related), in addition to the codes developed in the following procedures.

2.2. Codebook Development and Coding Procedures

To achieve a sample of tweets that were first-person (i.e., the point of view of the individual tweeter), we included codes to indicate if the tweet contained primarily *news* (i.e., headlines related to JUUL) or *commercial* content (i.e., marketing messages); these tweets (n = 74) were excluded from final analysis. The remaining codes, which were informed by current literature related to ENDS use and dependence, as well as traditional cigarette dependence (Case et al., 2018; Fagerstrom, 2012; Soule et al., 2016; Wheeler et al., 2004), were developed through an inductive process by which random sub-sets of 100 tweets—not included in the final sample— were analyzed by two experienced independent coders. These included codes related to *dependence* (i.e., the individual mentions dependence on JUUL, mentions compulsion to use, mentions use upon awakening); *acute nicotine effects* (i.e., mention of physical effects such as a buzz, light-headedness, or nausea); *quitting JUUL* (i.e., the individual states that s/he quit using JUUL or desire to quit); and *withdrawal* (i.e., the individual states that s/he is in withdrawal from JUUL or mentions symptoms related to withdrawal, such as cravings). To assist coders, the final codebook included operationalized definitions for each code (Table 1).

Our iterative coding process involved double-coding by two independent coders and adjudication of disagreements with senior researchers, followed by modifications of the codebook. Inter-rater reliability was assessed using Cohen's κ and percent agreement scores (Cohen, 1960). After 7 rounds of this process, all applicable codes reached acceptable levels of reliability (Landis and Koch, 1977) with κ coefficients ranging from 0.62 to 1.00. After the final codebook was established, the two coders each independently coded half of the final dataset. Tweets that were coded primarily news or commercial content (n = 74) were excluded from the final dataset. Additionally, some tweets are comments on another user's tweets with the original tweet in quotes. For this study, it was decided a priori to code first-person tweets. Therefore, if the original tweet contained JUUL-related messaging, but the tweet from the individual that we were coding did not, that tweet was considered irrelevant. These processes led to a final data set of 1986 tweets for final analysis.

2.3. Data Analysis

Frequencies and percentages were calculated for each categorical code. We then utilized a thematic qualitative content analysis approach (Braun and Clarke, 2006) to inductively assess the tweets related to *dependence*, *acute nicotine effects*, *quitting JUUL*, and *withdrawal*. Individual tweets could contain multiple codes, i.e. a tweet could discuss both *dependence* and *withdrawal*. Through this process, tweets within each of the codes were tabulated and reviewed for thematic trends by a coder who conducted earlier categorical coding. The coder first highlighted specific words or phrases within tweets which indicated salient (i.e., representative of the category) or novel (i.e., unique and potentially interesting)

content, and recorded memos about emergent themes within categories. These annotations and memos were further reviewed with supervising researchers to develop and refine thematic units within codes. For cohesiveness, the resulting themes are described and exemplified within their overarching categorical codes in the results section.

3. Results

A total of 420/1986 tweets (21.1%) from our data set were coded as being related to *dependence*, *acute nicotine effects*, *quitting JUUL*. and/or *withdrawal*. Of these tweets, 142 were coded as belonging to more than one of these categories (n=138 in two categories and n=4 in three categories). The most common co-occurrence was dependence and acute nicotine effects, accounting for 132 of these cases. The 1566 (78.9%) tweets that were not coded as relevant to the categories of primary interest were diverse due to the 20 keyword stems used to filter tweets. For example, the stem "*want**" appeared in other contexts (e.g.,an individual complaining that friends want his/her juul). Additionally, the "*quit**" stem appeared in other contexts, such as ridiculing others for using juul and suggesting they quit.

3.1. Themes Related to Dependence.

A total of 335/1986 (16.9%) tweets contained references to *dependence*, which generally contained messages related to self-reported "addiction" (i.e., reporting that one can become dependent on JUUL or reporting dependence on JUUL), or other indication that there was a "need" for the device, the pods, or the charger. Further qualitative analysis of these tweets sought to explore self-report of dependence, rather than analyzing the dependence experienced by others. A total of 217 tweets were coded as containing references to individuals being dependent on JUUL or needing JUUL. Of these, more than half (n = 130) contained language that indicated self-report of dependence. Some tweets expressed a need for pods, a charger, or the device itself (i.e., variations *of "gotta have my juul fix,"* n = 65), while others self-identified as dependent on JUUL (e.g., *"I'm becoming a juul addict,"* n = 53). Additionally, a total of 34 dependence-related tweets discussed self-report of using JUUL upon awakening (e.g., variations *of "wake up and hit the juul"*).

3.2. Themes Related to Acute Nicotine Effects.

There were 189/1986 (9.5%) tweets coded as referencing *nicotine* and JUUL. Of these, 27 contained self-report of *acute nicotine effects*, which generally included indications that one was experiencing physical effects of nicotine while using JUUL. These included feeling buzzed, experiencing dizziness or light-headedness, and feeling high. Although some of these tweets mentioned the acute nicotine affects light-heartedly (e.g., "*I live my life in a constant juul buzz*"), some of them displayed some expressions of concern, such as experience of headaches (e.g., "…*now my head hurts*"), passing out (e.g.,"…*almost passed out from being lightheaded*"), and concerns of nicotine poisoning (e.g., "…*I had nicotine poisoning*").

3.3. Themes Related to Quitting and Withdrawal.

A total of 36/1986 (1.8%) tweets were coded as referencing *quitting* JUUL (n = 36), which focused on the user wanting to quit JUUL or actually doing so. One theme was that the

individual stated that s/he is currently in the process of quitting (n = 7). Other themes related to quitting JUUL included expressing desire to quit (n = 13) and statements that the individual has recently quit (n = 6). Additionally, a total of 6/1986 (0.3%) tweets were coded as referencing *withdrawal* from JUUL, most of which discussed the physical effects of withdrawal (e.g., *"cold sweats*") or stated that going through withdrawal from JUUL was an uncomfortable or undesirable process.

4. Discussion

The results of this study indicate that some individuals who use JUUL may be experiencing dependence and acute nicotine effects while using the product. Considering that JUUL is marketed as a device to be used in place of traditional cigarettes (JUUL Labs Inc., 2018a), it is conceivable that use of JUUL could lead to similar experiences of nicotine dependence as using traditional cigarettes. For example, exposure to nicotine from cigarette smoking triggers the release of dopamine, eliciting feelings of pleasure and contributing to the highly addictive nature of cigarettes (Herman et al., 2014). Findings from this study indicate that JUUL users experience similar pleasurable feelings, such as a "buzz" or "high." Additionally, this study revealed that some individuals use JUUL first thing in the morning, which is consistent with research on dependence on ENDS and other nicotine-containing products such as cigarettes and waterpipe tobacco (Fagerström, 2012; Sidani et al., 2016).

It is not surprising that this surveillance of JUUL discussions on Twitter revealed indications of nicotine effects and dependence. Compared with other ENDS, JUUL delivers a powerful dose of nicotine (JUUL Labs Inc., 2018b) in amounts greater than most first-generation ENDS (Jackler and Ramamurthi, 2019). Additionally, JUUL utilizes a nicotine salt formulation, which is not only designed to increase the rate of absorption (Bowen and Xing, 2014), but also to deliver a vapor that is less harsh and more palatable to the user when compared to free base nicotine, which may facilitate inhalation and continued use (Jackler and Ramamurthi, 2019). One study examining posts on Reddit—a discussion-oriented social media platform—found that approximately 20% of posts discussing reasons for use of JUUL mentioned to "get a buzz" (Brett et al., 2019). However, many individuals report initiating ENDS use for taste and entertainment—not necessarily for nicotine exposure (Colditz et al., 2019; Evans-Polce et al., 2018; Hong et al., 2019)—so the effects of the nicotine in JUUL may have been unanticipated by some of these users.

This study also found that some users of JUUL want to quit using the product, and that some have trouble doing so, including experiencing withdrawal symptoms. To date, there is little research on withdrawal from ENDS products. An analysis of the Population Assessment of Tobacco and Health (PATH) cohort study found that approximately 25% of individuals who quit using ENDS met the DSM-V criteria for withdrawal (Hughes and Callas, 2018). Difficulty quitting traditional cigarette products has been well established (Fiore et al., 2008), and users of other nicotine and tobacco products, such as waterpipe tobacco, have similarly reported difficulty in quitting (Aboaziza and Eissenberg, 2015). Considering the amount of nicotine in JUUL (Jackler and Ramamurthi, 2019), it is not surprising that these discussions of difficulty quitting JUUL and related withdrawal symptoms are present on Twitter.

One of the concerns about the potential for dependence on JUUL is that it is particularly appealing to young people (Vallone et al., 2018). Although the company states that it does not intend to target underage individuals (JUUL Labs Inc., 2019a), they had, until very recently, a robust presence on social media, including Twitter, Instagram, and YouTube (Huang et al., 2018). The messaging on these platforms could be misleading and potentially problematic. For example, on July 10, 2018, the official JUUL Twitter account tweeted a picture of the device with the message, "#*JUUL is simple and satisfying. And it's not an e-cigarette. Here's why*" with a link to a page on their website titled, "JUUL- Not Your Average E-cigarette" (JUUL Labs Inc., 2019b; Tiku, 2018). Additionally, despite JUUL's announcement that it is suspending most of its US-based social media presence (JUUL Labs Inc., 2019a), JUUL's messages have already been spread effectively through social networks on social media, including those that include individuals under 18 (Chu et al., 2018). Finally, JUUL pods are available in a variety of flavors, including fruit and mango, which are associated with youth preference for ENDS (Shang et al., 2018).

There is also a concern that a "nicotine arms race" will spur the introduction of ENDS products with even greater nicotine concentrations into the market, as research has found indications of JUUL "copycats" and JUUL-compatible pods available online that contain even higher amounts of nicotine than JUUL (Jackler and Ramamurthi, 2019). Considering evidence that using ENDS with higher nicotine concentrations increases the risk of higher frequency and intensity of both ENDS and cigarette use among adolescents (Goldenson et al., 2017), the availability of high nicotine-containing ENDS products and their potential for dependence should be further examined. On the contrary, there is also evidence that individuals who use ENDS products with low nicotine concentrations may consume a greater amount of e-liquid as they attempt to achieve cigarette-like nicotine delivery (Wagener et al., 2017), which may exposure users to higher amounts of potentially harmful non-nicotine constituents. The effects and behaviors surrounding nicotine content of ENDS products can be investigated through continued monitoring of user experiences via social media—especially as it relates to the effects of nicotine and potential dependence—which will likely be a valuable tool as the ENDS market continues to evolve. Considering there is an association between posting positively about tobacco-related products and actual use (Unger et al., 2018), introducing educational messaging about ENDS and the high nicotine content of JUUL in social networks that frequently post positively about JUUL may be a beneficial intervention. For example, it may be possible to employ a Twitter bot to use machine learning to identify tobacco users and match them with former tobacco users who may help them decrease their tobacco use (Deb et al., 2018). Researchers can also continue to monitor discussions related to use of high-nicotine devices and pods to determine if there are additional anecdotal reports of dependence and difficulty quitting these devices. This future research could also be conducted through other platforms in addition to Twitter; researchers have found a wealth of information about user experiences related to JUUL on platforms such as Reddit and YouTube (Brett et al., 2019; Huang et al., 2018; Kavuluru et al., 2019). It may also be useful to examine further the potential difficulty of quitting ENDS products. Considering dependence has been associated with failed quit attempts in ENDS users (Garey et al., 2019), there is a possibility that some JUUL users who want to quit will be unsuccessful.

4.1. Limitations

The results of this study should be considered with regard to the following limitations. First, Twitter does not represent the population at large, and the results of this study cannot be generalized to individuals who do not use Twitter. However, these data can offer timely qualitative insights into emergent trends that may be difficult to detect in more representative population studies. Additionally, this study was designed to collect tweets that specifically mentioned themes related to nicotine effects, dependence, and withdrawal and are therefore not representative of all JUUL-related tweets. Another limitation is that interrater reliability for some of the coded variables, while considered to be substantial agreement based on published standards (Landis and Koch, 1977), did not reach perfect agreement. Finally, ages and other latent characteristics of Twitter users were not ascertained in this study, primarily because tweet-level data, as opposed to more extensive user-level data, are not conducive to identifying such characteristics. Thus, the results of this study cannot be ascribed only to youth or young adults, as the age of the individual Twitter users were not ascertained. This limitation remains an area of continued research interest.

4.2. Conclusions

In conclusion, this qualitative analysis of JUUL-related tweets found themes related to dependence, acute nicotine effects, and difficulty quitting use of the product. To our knowledge, this is the first analysis of self-reported dependence on JUUL or the physical effects usually associated with nicotine exposure using Twitter data. This study extends the current research pertaining to JUUL on Twitter, which has focused on sentiment, discussions about use, and communication between individuals (Allem et al., 2018; Chu et al., 2018; Kavuluru et al., 2019) to also examine how JUUL users discuss their experience with the product in terms of nicotine effects, dependence, and withdrawal. Because of JUUL's high nicotine content and patented nicotine salts formulation (Bowen and Xing, 2014; Jackler and Ramamurthi, 2019), it is not surprising that users have discussed feeling nicotine and dependence-related effects. It will be important to continue to monitor discussions related to acute nicotine effects, self-reported dependence, and difficulty quitting JUUL, as well as even higher nicotine content ENDS products as they continue to appear on the market (Jackler and Ramamurthi, 2019).

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References

Aboaziza E, Eissenberg T, 2015 Waterpipe tobacco smoking: What is the evidence that it supports nicotine/tobacco dependence? Tob. Control 24, i44–i53. 10.1136/tobaccocontrol-2014-051910 [PubMed: 25492935]

Allem J-P, Dharmpuri L, Unger JB, Cruz TB, 2018 Characterizing Juul-related posts on Twitter. Drug Alcohol Depend. 190, 1–5. https://doi.Org/10.1016/j.drugalcdep.2018.05.018 [PubMed: 29958115]

Anderson M, Jiang J, 2018 Teens, social media & technology 2018 [WWW Document]. Pew Res. Cent URL http://www.pewinternet.org/2018/05/31/teens-social-media-technology-2018/ (accessed 6.3.19).

Barrington-Trimis JL, Urman R, Berhane K, Unger JB, Cruz TB, Pentz MA, Samet JM, Leventhal AM, McConnell R, 2016 E-cigarettes and future cigarette use. Pediatrics 138, e20160379–e20160379. 10.1542/peds.2016-0379 [PubMed: 27296866]

Berry N, Lobban F, Belousov M, Emsley R, Nenadic G, Bucci S, 2017 # WhyWeTweetMH: Understanding why people use Twitter to discuss mental health problems. J. Med. Internet Res 19, e107 10.2196/jmir.6173 [PubMed: 28381392]

Bowen A, Xing C, 2014 Nicotine salt formulations for aerosol devices and methods thereof. US 9215895B2

Braun V, Clarke V, 2006 Using thematic analysis in psychology. Qual. Res. Psychol 3, 77–101. 10.1191/1478088706qp063oa

Brett EI, Stevens EM, Wagener TL, Leavens ELS, Morgan TL, Cotton WD, Hébert ET, 2019 A content analysis of JUUL discussions on social media: Using Reddit to understand patterns and perceptions of JUUL use. Drug Alcohol Depend 194, 358–362. 10.1016/j.drugalcdep.2018.10.014 [PubMed: 30472576]

Broniatowski DA, Paul MJ, Dredze M, 2013 National and local influenza surveillance through Twitter: An analysis of the 2012–2013 influenza epidemic. PLoS One 8, e83672 10.1371/journal.pone.0083672 [PubMed: 24349542]

Case KR, Mantey DS, Creamer MR, Harrell MB, Kelder SH, Perry CL, 2018 E-cigarette- specific symptoms of nicotine dependence among Texas adolescents. Addict. Behav 84, 57–61. 10.1016/j.addbeh.2018.03.032 [PubMed: 29627634]

Chu K, Colditz JB, Primack BA, Shensa A, Allem J, Miller E, Unger JB, Cruz TB, 2018 JUUL: spreading online and offline. J. Adolesc. Heal 63, 582–586. 10.1016/j.jadohealth.2018.08.002

Cohen J, 1960 A coefficient of agreement for nominal scales. Educ. Psychol. Meas 20, 37–46. 10.1177/001316446002000104

Colditz JB, Chu K, Emery SL, Larkin CR, James AE, Welling J, Primack BA, 2018 Toward real-time infoveillance of Twitter health messages. Am. J. Public Health 108, 1009–1014. 10.2105/AJPH.2018.304497 [PubMed: 29927648]

Colditz JB, Welling J, Smith NA, James AE, Primack BA, 2019 World Vaping Day: Contextualizing vaping culture in online social media using a mixed methods approach. J. Mix. Methods Res 13, 196–215. 10.1177/1558689817702753

Deb A, Majmundar A, Seo S, Matsui A, Tandon R, Yan S, Allem J-P, Ferrara E, 2018 Social bots for online public health interventions, in: 2018 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM). IEEE, pp. 1–4. 10.1109/ASONAM.2018.8508382

Evans-Polce RJ, Patrick ME, Lanza ST, Miech RA, O'Malley PM, Johnston LD, 2018 Reasons for vaping among U.S. 12th graders. J. Adolesc. Heal 62, 457–462. 10.1016/j.jadohealth.2017.10.009

Fagerström K, 2012 Determinants of tobacco use and renaming the FTND to the Fagerstrom Test for cigarette dependence. Nicotine Tob. Res 14, 75–78. 10.1093/ntr/ntr137 [PubMed: 22025545]

Fear NT, Seddon R, Jones N, Greenberg N, Wessely S, 2012 Does anonymity increase the reporting of mental health symptoms? BMC Public Health 12, 797 10.1186/1471-2458-12-797 [PubMed: 22985427]

Fiore MC, Jaen CR, Baker TB, Bailey WC, Bennett G, Benowitz N, Christiansen BA, Connell M, Curry SJ, Dorfman SF, Fraser D, Froelicher ES, Goldstein MG, Hasselblad V, Healton CG, Heishman S, Henderson PN, Heyman RB, Husten C, Koh HK, Kottke TE, Lando HA, Leitzke C, Mecklenburg RE, Mermelstein RJ, Morgan G, Mullen PD, Murray EW, Orleans CT, Piper ME, Robinson L, Stitzer ML, Theobald W, Tommasello AC, Villejo L, Wewers ME, Williams C, 2008 A clinical practice guideline for treating tobacco use and dependence: 2008 update: A U.S. public health service report. Am. J. Prev. Med 35, 158–176. 10.1016/j.amepre.2008.04.009 [PubMed: 18617085]

Garey L, Mayorga NA, Peraza N, Smit T, Nizio P, Otto MW, Zvolensky MJ, 2019 Distinguishing characteristics of e-cigarette users who attempt and fail to quit: dependence, perceptions, and affective vulnerability. J. Stud. Alcohol Drugs 80, 134–140. 10.15288/jsad.2019.80.134 [PubMed: 30807286]

Goldenson NI, Leventhal AM, Stone MD, McConnell RS, Barrington-Trimis JL, 2017 Associations of electronic cigarette nicotine concentration with subsequent cigarette smoking and vaping levels in adolescents. JAMA Pediatr 171, 1192 10.1001/jamapediatrics.2017.3209 [PubMed: 29059261]

Goniewicz ML, Boykan R, Messina CR, Eliscu A, Tolentino J, 2018 High exposure to nicotine among adolescents who use Juul and other vape pod systems ('pods'). Tob. Control tobaccocontrol-2018–054565 10.1136/tobaccocontrol-2018-054565

Herman AI, DeVito EE, Jensen KP, Sofuoglu M, 2014 Pharmacogenetics of nicotine addiction: Role of dopamine. Pharmacogenomics 15, 221–234. 10.2217/pgs.13.246 [PubMed: 24444411]

Hong H, McConnell R, Liu F, Urman R, Barrington-Trimis JL, 2019 The impact of local regulation on reasons for electronic cigarette use among Southern California young adults. Addict. Behav 91, 253–258. 10.1016/j.addbeh.2018.11.020 [PubMed: 30503511]

Huang J, Duan Z, Kwok J, Binns S, Vera LE, Kim Y, Szczypka G, Emery SL, 2018 Vaping versus JUULing: How the extraordinary growth and marketing of JUUL transformed the US retail e-cigarette market. Tob. Control 1–10 10.1136/tobaccocontrol-2018-054382

Hughes JR, Callas PW, 2018 Prevalence of withdrawal symptoms from electronic cigarette cessation: A cross-sectional analysis of the US Population Assessment of Tobacco and Health. Addict. Behav 10.1016/j.addbeh.2018.07.002

Jackler RK, Ramamurthi D, 2019 Nicotine arms race: JUUL and the high-nicotine product market. Tob. Control tobaccocontrol-2018–054796 10.1136/tobaccocontrol-2018-054796

JUUL Labs Inc., 2019a JUUL: Youth prevention [WWW Document]. URL https://www.juul.com/youth-prevention (accessed 4.15.19).

JUUL Labs Inc., 2019b JUUL- not your average e-cigarette [WWW Document]. URL https://support.juul.com/learn/read/JUUL-Not-Your-Average-E-cigarette?utm_source=SocialMedia&utm_medium=Twitter&utm_campaign=Learn Center E cigarette(accessed 4.15.19).

JUUL Labs Inc., 2018a JUUL: Our mission [WWW Document]. URL https://www.juul.com/ (accessed 4.15.19).

JUUL Labs Inc., 2018b JUULpod basics [WWW Document]. URL https://support.juul.com/home/learn/faqs/juulpod-basics (accessed 4.15.19).

Kavuluru R, Han S, Hahn EJ, 2019 On the popularity of the USB flash drive-shaped electronic cigarette Juul. Tob. Control 28, 110–112. 10.1136/tobaccocontrol-2018-054259 [PubMed: 29654121]

Kim AE, Chew R, Wenger M, Cress M, Bukowski T, Farrelly M, Hair E, 2019 Estimated ages of JUUL Twitter followers. JAMA Pediatr. epub ahead of print 10.1001/jamapediatrics.2019.0922

King BB, Gammon DG, Marynak KL, Rogers T, 2018 Electronic cigarette sales in the United States, 2013–2017. JAMA 320, 1379 10.1001/jama.2018.10488 [PubMed: 30285167]

King JL, Reboussin D, Cornacchione Ross J, Wiseman KD, Wagoner KG, Sutfin EL, 2018 Polytobacco use among a nationally representative sample of adolescent and young adult e-cigarette users. J. Adolesc. Heal 63, 407–412. 10.1016/j.jadohealth.2018.04.010

Landis JR, Koch GG, 1977 The measurement of observer agreement for categorical data. Biometrics 33, 159–174. 10.2307/2529310 [PubMed: 843571]

LaVito A, 2018a Popular e-cigarette Juul's sales have surged almost 800 percent over the past year [WWW Document]. CNBC URL https://www.cnbc.com/2018/07/02/juul-e-cigarette-sales-have-surged-over-the-past-year.html (accessed 4.15.19).

LaVito A, 2018b Leading e-cig maker Juul to sell lower-nicotine pods as scrutiny ratchets higher [WWW Document]. CNBC URL https://www.cnbc.com/2018/07/11/juul-to-introduce-lower-nicotine-pods-for-some-of-its-flavors.html (accessed 4.15.19).

Lienemann BA, Unger JB, Cruz TB, Chu K-H, 2017 Methods for coding tobacco-related Twitter data: A systematic review. J. Med. Internet Res 19, e91 10.2196/jmir.7022 [PubMed: 28363883]

Marsot A, Simon N, 2016 Nicotine and cotinine levels with electronic cigarette: a review. Int. J. Toxicol 35, 179–185. 10.1177/1091581815618935 [PubMed: 26681385]

Martinez LS, Hughes S, Walsh-Buhi ER, Tsou M-H, 2018 "Okay, we get it. You vape": An analysis of geocoded content, context, and sentiment regarding e-cigarettes on Twitter. J. Health Commun 23, 550–562. 10.1080/10810730.2018.1493057 [PubMed: 29979920]

Morean ME, Kong G, Cavallo DA, Camenga DR, Suchitra K, 2016 Nicotine concentration of e-cigarettes used by adolescents. Drug Alcohol Depend 70, 773–779. 10.1097/OGX.0000000000000256.Prenatal

Primack BA, Shensa A, Sidani JE, Hoffman BL, Soneji S, Sargent JD, Hoffman RM, Fine MJ, 2018 Initiation of traditional cigarette smoking after electronic cigarette use among tobacco-naive US young adults. Am. J. Med 131, 443.e1–443.e9. 10.1016/j.amjmed.2017.11.005

Primack BA, Soneji S, Stoolmiller M, Fine MJ, Sargent JD, 2015 Progression to traditional cigarette smoking after electronic cigarette use among US adolescents and young adults. JAMA Pediatr 169, 1018–1023. 10.1001/jamapediatrics.2015.1742 [PubMed: 26348249]

Rohde J, Noar S, Horvitz C, Lazard A, Cornacchione Ross J, Sutfin E, 2018 The role of knowledge and risk beliefs in adolescent e-cigarette use: A pilot study. Int. J. Environ. Res. Public Health 15, 830 10.3390/ijerph15040830

Shang C, Huang J, Chaloupka FJ, Emery SL, 2018 The impact of flavour, device type and warning messages on youth preferences for electronic nicotine delivery systems: Evidence from an online discrete choice experiment. Tob. Control 27, e152–e159. 10.1136/tobaccocontrol-2017-053754 [PubMed: 29097588]

Sidani JE, Shensa A, Shiffman S, Switzer GE, Primack BA, 2016 Behavioral associations with waterpipe tobacco smoking dependence among US young adults. Addiction 111, 351–359. 10.1111/add.13163 [PubMed: 26417942]

Sinnenberg L, Buttenheim AM, Padrez K, Mancheno C, Ungar L, Merchant RM, 2017 Twitter as a tool for health research: A systematic review. Am. J. Public Health 107, e1–e8. 10.2105/AJPH.2016.303512

Smith A, Anderson M, 2018 Social media use in 2018 [WWW Document]. URL https://www.pewinternet.org/2018/03/01/social-media-use-in-2018/ (accessed 5.7.19).

Soule EK, Nasim A, Rosas S, 2016 Adverse effects of electronic cigarette use: A concept mapping approach. Nicotine Tob. Res 18, 678–685. 10.1093/ntr/ntv246 [PubMed: 26563262]

Tiku N, 2018 JUUL's lobbying could send its public image up in smoke [WWW Document]. Wired URL https://www.wired.com/story/juuls-lobbying-could-send-its-public-image-up-in-smoke/ (accessed 4.15.19).

U.S. Food and Drug Administration, 2018 Statement from FDA Commissioner Scott Gottlieb, M.D., on new enforcement actions and a Youth Tobacco Prevention Plan to stop youth use of, and access to, JUUL and other e-cigarettes [WWW Document]. URL https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm605432.htm (accessed 4.15.19).

Unger JB, Urman R, Cruz TB, Majmundar A, Barrington-Trimis J, Pentz MA, McConnell R, 2018 Talking about tobacco on Twitter is associated with tobacco product use. Prev. Med. (Baltim) 114, 54–56. 10.1016/j.ypmed.2018.06.006

Vallone DM, Bennett M, Xiao H, Pitzer L, Hair EC, 2018 Prevalence and correlates of JUUL use among a national sample of youth and young adults. Tob. Control 10.1136/tobaccocontrol-2018-054693

Vogel EA, Ramo DE, Rubinstein ML, 2018 Prevalence and correlates of adolescents' e-cigarette use frequency and dependence. Drug Alcohol Depend 188, 109–112. 10.1016/j.drugalcdep.2018.03.051 [PubMed: 29763848]

Wagener TL, Floyd EL, Stepanov I, Driskill LM, Frank SG, Meier E, Leavens EL, Tackett A, Molina N, Queimado L, 2017 Have combustible cigarettes met their match? The nicotine delivery profiles and harmful constituent exposures of second-generation and third-generation electronic cigarette users. Tob. Control 26, e23–e28. 10.1136/tobaccocontrol-2016-053041 [PubMed: 27729564]

Wheeler KC, Fletcher KE, Wellman RJ, Difranza JR, 2004 Screening adolescents for nicotine dependence: The hooked on nicotine checklist. J. Adolesc. Heal 35, 225–230. 10.1016/j.jadohealth.2003.10.004

Willett JG, Bennett M, Hair EC, Xiao H, Greenberg MS, Harvey E, Cantrell J, Vallone D, 2019 Recognition, use and perceptions of JUUL among youth and young adults. Tob. Control 28, 115–116. 10.1136/tobaccocontrol-2018-054273 [PubMed: 29669749]

Highlights

- Twitter can be used to analyze messages about nicotine, dependence, and withdrawal.
- Users of JUUL are self-reporting symptoms of nicotine exposure and dependence.
- Dependence tweets included use upon waking, compulsion, and inability to cut down.
- Nicotine exposure tweets revealed themes related to self-reported physical effects.
- Due to JUUL's rising popularity and high nicotine content, more research is needed.

Table 1.

Definitions for categorical codes and example tweets.

Code / *Sub-code*	Definition	Example content
Dependence	The tweet mentions JUUL in association with words that specify dependence or a need to smoke JUUL.	• Can't even get through an entire class period without needing to go juul lol. • Why is it that…people who vape actually never been addicted to tobacco… everybody 's got a juul. • At least I don't have a juul/nicotine addiction.
Self-report	The tweet contains language that describes self-reported addiction, rather than that experienced by others.	• I am in desperate need of mango juul pods. • I'm addicted to my juul. • Nothing is better than a juul headrush in the morning. • I quit smoking cold turkey for a decad. chewed gum and blew bubbles (yes) to handle fidgets; but got through it. juul has me addicted once again… • When you start juuling to not be addicted to cigarettes but instead of leaving for 5 minutes every couple hours you twitch and have a panic attack if you don't know where the juul is for 30 seconds
Nicotine	The tweet mentions nicotine or nicotine effects.	• Juuls are guaranteed to give you a nicotine addiction & other health problems because you had to look cool and have a bigger smoke cloud than [name]. • this guy is tweeting hes buzzed off a juul and acting like he is [expletive] i dont understand.
Self-report	The tweet contains language that describes self-reported experience of nicotine effects, rather than that experienced by others.	• Hitting the juul right when I wake up always gives me a buzz before school. • I only juul because they give you a good drunk buzz for like 2 minutes. • Yooo juuls get u higher than I thought fr. • I took a two day tolerance break from my juul; swear my first hit got me tilted • I live my life in a constant juul buzz.
Quitting JUUL	The tweet mentions the tweeter has or wants to quit smoking JUUL.	• I'm quitting the juul… • I really want to stop smoking this JUUL. Like yeah, it 's not cigarettes but I don't feel like being addicted to nicotine. • Someone please tell me how…to quit juuling. • I just threw my juul away.
Withdrawal	The tweet mentions symptoms/effects of the absence of a JUUL.	• I need my juul, I get a headache every time I lose it. • These withdrawals are killing me.

*Proper names and expletives have been censored. Minor details of tweet content were changed to prevent re-identification of individual Twitter users via direct quotes.

[a]If a tweet was determined to be "news" or "commercial," it was not coded further and was excluded from final analyses.