E-liquid-related posts to Twitter in 2018: Thematic analysis

Jon-Patrick Allem[a,*], Anuja Majmundar[a], Likhit Dharmapuri[b], Tess Boley Cruz[a], Jennifer B. Unger[a]

[a] Keck School of Medicine, University of Southern California, Los Angeles, CA, USA
[b] Department of Computer Science, University of Southern California, Los Angeles, CA, USA

ARTICLE INFO

ABSTRACT

Introduction: E-liquid is the solution aerosolized by e-cigarette devices to produce vapor. Continuously evolving e-liquids, and corresponding devices, can affect user experiences associated with these products. Twitter conversations about e-liquids can capture salient behavioral, social, and communicative cues associated with e-liquids. We analyzed Twitter data to characterize key topics of conversation about e-liquids to inform surveillance, and regulatory efforts.
Methods: Twitter posts containing e-liquid-related terms ("e-liquid(s)," "e-juice(s)") were obtained from 1 January 2018 to 31 December 2018. Text classifiers were used to identify topics of the posts (n = 15,927).
Results: The most prevalent topic was *Promotional* at 29.35% followed by *Flavors* at 24.22%, and *Person Tagging* at 21.47%. *Juice Composition* was next most prevalent at 17.61% followed by *Cannabis* at 16.83%, and *Nicotine Health Risks* at 6.39%. *Quit Smoking* was rare at 0.57%.
Conclusion: These results suggest that flavors, cannabis, health risks of nicotine, and composition warrant consideration as targets in future surveillance, public policy, and interventions addressing the use of e-liquids. Twitter provides ample opportunity to influence the normalization, and uptake, of e-cigarette-related products among non-smokers and youth, unless regulatory restrictions, and counter messaging campaigns are developed to reduce this risk.

1. Introduction

E-liquid is the solution aerosolized by e-cigarette devices to produce vapor. These liquids come in a variety of flavors (Marynak et al., 2017; Zhu et al., 2014) that are linked with greater perceived enjoyment (Soule, Lopez, Guy, & Cobb, 2016), and lower harm perceptions compared to combustible cigarettes (Pepper, Ribisl, & Brewer, 2016), and e-cigarettes initiation in youth (Zare, Nemati, & Zheng, 2018). They also have varied nicotine concentrations (Etter, Zäther, & Svensson, 2013; Goniewicz, Hajek, & McRobbie, 2014; Goniewicz, Kuma, Gawron, Knysak, & Kosmider, 2013), with implications for abuse liability wherein higher concentrations are associated with higher yields of nicotine, an addictive substance (Talih et al., 2017). These products and corresponding devices are constantly evolving, which could affect user experiences associated with these products, and have public health consequences. One rapid method to identify evolving products, and salient topics, is to analyze Twitter conversations that capture these user experiences in addition to social, and communicative cues associated with e-liquid use. Posts to Twitter provide an opportunity for public health researchers to understand public sentiment, attitudes, and behaviors by examining how people naturally discuss different topics of import in their own words. In this way, aggregated posts to Twitter can serve as a large focus group.

Prior research on e-cigarette-related posts to Twitter through the year 2018 provide insight into e-cigarette use, including the occurrence of dual tobacco product use (e.g., e-cigarettes and hookah) (Allem, Ferrara, Uppu, Cruz, & Unger, 2017), the appeal of flavors and other design features (e.g., small size) (Kavuluru, Han, & Hahn, 2019), and clandestine use in places where tobacco is prohibited (e.g., use on school grounds during class time) (Allem, Dharmapuri, Unger, & Cruz, 2018). In the present study, we used Twitter data to describe e-liquid conversations in 2018. Twitter is used by 22% of U.S. adults (24% of men, 21% of women, 21% of whites, 24% of African Americans 25% of Hispanics) with 42% of users on the platform at least once a day (Perrin & Anderson, 2018). Additionally, Twitter is used by 32% of adolescents (13 to 17 years) in the U.S. (Anderson & Jiang, n.d.). Our goal is to determine the public's recent experiences with e-liquids.

* Corresponding author at: 2001 N. Soto Street, 3rd Floor Mail, Los Angeles, CA 90032, USA.
E-mail address: allem@usc.edu (J.-P. Allem).

2. Methods

2.1. Data collection

Twitter (https://twitter.com/) posts containing e-liquid-related terms ("e-liquid(s)," "e-juice(s),") were obtained from 1 January 2018 to 31 December 2018. These terms were informed by prior research on e-liquids utilizing data from social media (Allem et al., n.d.). There was a total of n = 85,803 posts containing these terms during this time from 21,598 users. To prepare the data for analyses, we excluded non-English tweets, retweets, and tweets from accounts identified as social bots (Allem & Ferrara, 2016), resulting in a final analytic sample of n = 15,927 tweets, from 4590 unique users.

Tweets in the analytic sample were normalized through lemmatization (which converts words to meaningful base forms, e.g., "liquids" becomes "liquid"), converted to lower case, and processed by removing English language stopwords (e.g., words that appear commonly in-text but do not add context to the topics of conversation such as "the"), numbers, punctuation, special characters, hyperlinks and hashtags (Allem, Dharmapuri, Leventhal, Unger, & Cruz, 2018; Allem, Dharmapuri, Unger, & Cruz, 2018). Usernames mentioned in tweets were labelled "@person" to protect the identity of the individuals. All analyses relied on public, anonymized data, adhered to the terms and conditions, terms of use, and privacy policies of Twitter, and were performed under Institutional Review Board approval from the authors' university. To protect privacy, no tweets were reported verbatim in this report.

As part of exploratory analyses, we analyzed the tweets using word frequencies (unigrams and bigrams), and visualized the data through word clouds to identify common topics (see Supplemental material). From this assessment, the authors arrived at consensus on six commonly occurring topics including, *Promotional* (mentions of giveaways, purchases, etc.), *Flavors* (mentions of vanilla, candy, etc.), *Person Tagging* (e.g., @person), *Cannabis* (mentions of weed, CBD, etc.), *Juice Composition* (mentions of VG, PG [shorthand for vegetable glycerin and propylene glycol], milligrams of nicotine, etc.), and *Nicotine Health Risks* (mentions of nicotine's addictiveness and its harm to children, etc.). Although not a prominent topic but consistent with our prior research (Allem, Dharmapuri, Unger, & Cruz, 2018), we looked for words and phrases that suggested e-liquids were used to *Quit Smoking* (mentions of quitting cigarette smoking). Table 1 provides a list of common words found in posts along with the e-liquid-related terms. These words are meant to provide further context for each theme, are not exhaustive, and are listed in alphabetical order.

Each tweet was classified to one or more topics based on the presence of at least one topic-related unigram and/or bigram. We used a rule-based classification script written in Python where each tweet was checked for the presence of a specified set of n-grams representing a topic e.g., *Promotional*. For each analysis, we present findings in a confusion matrix where the diagonal line indicates the prevalence of a topic and the off-diagonal lines indicate topic overlap. For example, a hypothetical post such as "Hey! @person love my new cotton candy e-liquid!" would be classified under *Person Tagging* and *Flavor*. The number of posts containing both would be found at the intersection of the matrix for these 2 topics.

3. Results

The total coverage of the 7 topics constituted 74.87% of all tweets in the corpus (Fig. 1). The remaining 25.13% of tweets were too varied to be classified into a single topic with meaningful coverage (coverage of each subsequent topic would be less than 1% of total tweets). The most prevalent topic in the corpus was *Promotional* at 29.35% followed by *Flavors* at 24.22%, and *Person Tagging* at 21.47%. *Juice Composition* was next most prevalent at 17.62%, followed by *Cannabis* at 16.83%, and *Nicotine Health Risks* at 6.39%. *Quit Smoking* was rare at 0.57% of all tweets. *Juice Composition* and *Flavors* had the most overlap at 9.51% followed by *Cannabis* and *Promotional* at 6.84%.

4. Discussion

The topics identified in this study of e-liquid-related posts to Twitter in 2018 provide several insights about the public's recent experience with e-liquids. In line with previous research (Allem, Dharmapuri, Leventhal, et al., 2018), promotions were a predominant theme. In the absence of regulations controlling online promotions, post on platforms like Twitter can reach and potentially influence both current e-liquid users and non-users, adult and youth with few restrictions on content, or formal gateways restricting access to the content.

Recent analyses of Instagram posts containing e-liquid-related hashtags (#ejuice, #eliquid) have shown that e-liquid manufacturers and vendors use marketing strategies like cartoons to appeal to customers and potential customers (Allem et al., n.d.). The social media landscape provides ample opportunity to influence the uptake of e-cigarette-related products among non-smokers, and youth, and may warrant regulatory restrictions, and counter messaging campaigns.

Similar to prior research (Zhan, Liu, Li, Leischow, & Zeng, 2017), posts often discussed flavors. Compared to non-flavored tobacco products, flavored products are perceived to be more attractive and appealing (Choi, Fabian, Mottey, Corbett, & Forster, 2012). E-liquid marketing is focused on promoting flavors (Laestadius, Wahl, Pokhrel, & Cho, 2019), and is known to enhance appeal, and intentions to use more than advertisements for non-flavored products (Vasiljevic, Petrescu, & Marteau, 2016). Youth also believe that advertisements for flavored e-liquids target individuals similar to their own age (McKelvey, Baiocchi, Ramamurthi, McLaughlin, & Halpern-Felsher, 2019). Findings from this study highlight that flavors are one of the key topics of discussions related to e-liquids on Twitter, which supports FDA's recent announcement about the need to regulate sale of flavored e-liquids, and e-cigarette products (Food and Drug Administration, n.d.).

Person Tagging, or one Twitter user directly communicating to another about e-liquids, was also a common topic in this study, consistent

Table 1
Themes and common words found in posts along with e-liquid-related terms. These words are meant to provide further context for each theme, are not exhaustive and listed in alphabetical order.

Person Tagging	Promotional	Flavors	Cannabis	Juice Composition	Nicotine Health Risks	Quit Smoking
@person	Buy	Apple	CBD	50/50	Children	Quit smoking
	Deals	Banana	Hemp	80/20	Kid-friendly	
	Discount	Blueberry	Marijuana	Ml	Misleading kids	
	Giveaway	Candy	Weed	Mg	Nicotine	
	Free postage	Fruity		Pg		
	Free shipping	Flavors		Nicotine salts		
	Promotions	Mango		Vg		
	Purchase	Melon				
	Shop	Vanilla				
	Wholesale					

	Promotional	Flavors	Person Tagging	Juice Composition	Cannabis	Nicotine Health Risks	Quit Smoking
Promotional	**4675 (29.35%)**						
Flavors	495 (3.11%)	**3857 (24.22%)**					
Person Tagging	752 (4.72%)	567 (3.56%)	**3419 (21.47%)**				
Juice Composition	251 (1.51%)	1515 (9.51%)	500 (3.14%)	**2806 (17.62%)**			
Cannabis	1089 (6.84%)	768 (4.82%)	180 (1.13%)	436 (2.74%)	**2680 (16.83%)**		
Nicotine Health Risks	44 (0.28%)	166 (1.04%)	302 (1.90%)	216 (1.36%)	27 (0.17%)	**1018 (6.39%)**	
Quit Smoking	39 (0.24%)	13 (0.08%)	51 (0.32%)	3 (0.02%)	1 (0.01%)	2 (0.01%)	**90 (0.57%)**

Fig. 1. Prevalence of topics.

with prior research (Allem, Dharmapuri, Leventhal, et al., 2018; Allem, Dharmapuri, Unger, & Cruz, 2018). This finding demonstrates that Twitter users communicate their experiences with e-liquids with their friends and followers on Twitter. In other words, posts classified under 'person tagging' consistently used '@Person' tags to involve others in conversations about e-liquids.

Cannabis was a common topic in the present study. Compared to smoking cannabis, motivations for vaping cannabis, in general, include better taste, lower perceived health risks, and stronger drug impact in the form of higher concentrations of cannabinoids (Lee, Crosier, Borodovsky, Sargent, & Budney, 2016; Morean, Lipshie, Josephson, & Foster, 2017). Mixing nicotine and cannabis in vaporizers, is also an emerging trend, although additional research is warranted to examine the prevalence of this behavior (Knapp et al., 2019). The present study contextualizes discussions of cannabis use within the larger discourse about e-liquids given limited evidence about the prevalence or health effects of vaping cannabis (Budney, Sargent, & Lee, 2015). Future work should explore topics of conversation at the intersection of nicotine and cannabis.

The composition of e-liquids was discussed on Twitter in 2018. Awareness of e-liquid composition requires a nuanced understanding of the proportions of its constituents. Varying proportions of e-liquid VG/ PG content in combination with puff topography (e.g., number of puffs), and device architecture, determine e-cigarette users' experiences (such as throat hit, vapor clouds) and nicotine delivery (Baassiri et al., 2017). E-liquid composition has direct implications for appeal, and user experience, and potentially for the maintenance of longer-term use. For instance, producing bigger vape clouds is known to drive e-cigarette product appeal (Chu, Allem, Cruz, & Unger, 2016; Galstyan, Galimov, & Sussman, 2019). Older, regular smokers typically desire a throat hit that is similar to their regular combustible cigarettes (Sussman et al., 2016). In this evolving e-liquid product landscape, it is possible that knowledge of e-liquid composition allows users to adapt to and choose from the wide variety of these products. Conversations at the intersection of flavors and e-liquid composition, may potentially enhance the appeal of e-cigarettes. Such knowledge may be transmitted to Twitter influencing product preference, and may educate new users about ways to initiate, and maintain, product use.

The health risks of nicotine were also discussed suggesting Twitter users are concerned about the health consequences of nicotine. These types of messages may be amplified by public health practitioners to clarify the consequences of nicotine on adolescent development or other consequences. While health risks of nicotine were a common topic in the present study, the use of e-liquids to quit smoking combustible cigarettes was rarely mentioned. Similar to prior research utilizing Twitter (Allem, Dharmapuri, Unger, & Cruz, 2018), conversations about e-cigarette use and related products seldom mention cessation.

4.1. Limitations

This study focused on posts to Twitter, and findings may not generalize to other social media platforms. The posts analyzed in this study were collected from a 12-month period and may not generalize to other time periods. Data collection relied on Twitter's Streaming API, which prevented collection of tweets from private Twitter accounts. As a result, findings may not represent the attitudes and behaviors of individuals with private accounts. Findings may not generalize to the public. Mentions of CBD in Twitter posts were placed under the *Cannabis* topic, even though the presence of CBD in e-liquids may be significantly less problematic than other substances found in these products.

4.2. Concluding remarks

Promotions, social experiences, flavors, cannabis, health risks of nicotine, and liquid composition were common contexts associated with Twitter discussions about e-liquids in 2018. These results suggest that flavors, cannabis, health risks of nicotine, and liquid composition warrant consideration as targets in future surveillance, public policy, and interventions addressing the use of e-liquids. These conversations and posts containing product promotions take place with almost no restrictions on content, product claims or youth access. This study also highlights a clear benefit of using Twitter data in public health surveillance.

Role of funding source

Contributors

JPA and LD conceived of the study and analyzed the data. JPA and AM drafted the initial manuscript. TC, JU, and LD revised the manuscript for important intellectual content. TC and JU received funding for the study. All authors have approved the final manuscript.

Declaration of Competing Interest

The authors have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.abrep.2019.100196.

References

Allem JP, Cruz TB, Unger JB, Toruno R, Herrera J, Kirkpatrick M. Return of cartoon to market e-cigarette-related products. Tobacco Control. Epub ahead of print 26 July 2018. doi:https://doi.org/10.1136/tobaccocontrol-2018-054437.

Allem, J. P., Dharmapuri, L., Leventhal, A. M., Unger, J. B., & Cruz, T. B. (2018). Hookah-related posts to Twitter from 2017 to 2018: Thematic analysis. *Journal of Medical Internet Research, 20*(11), e11669.

Allem, J. P., Dharmapuri, L., Unger, J. B., & Cruz, T. B. (2018). Characterizing JUUL-related posts on Twitter. *Drug and Alcohol Dependence, 190*, 1–5.

Allem, J. P., & Ferrara, E. (2016). The importance of de-biasing social media data to better understand e-cigarette-related attitudes and behaviors. *Journal of Medical Internet Research, 18*(8), e219.

Allem, J. P., Ferrara, E., Uppu, S. P., Cruz, T. B., & Unger, J. B. (2017). E-cigarette surveillance with social media data: Social bots, emerging topics and trends. *JMIR Public Health and Surveillance, 3*(4), e98.

Anderson, M., & Jiang, J. Teens, social media & technology. From https://www.pewinternet.org/2018/05/31/teens-social-media-technology-2018/, Accessed date: 8 May 2019.

Baassiri, M., Talih, S., Salman, R., Karaoghlanian, N., Saleh, R., El Hage, R., ... Shihadeh, A. (2017). Clouds and "throat hit": Effects of liquid composition on nicotine emissions and physical characteristics of electronic cigarette aerosols. *Aerosol Science and Technology, 51*(11), 1231–1239.

Budney, A. J., Sargent, J. D., & Lee, D. C. (2015). Vaping cannabis (marijuana): parallel concerns to e-cigs? *Addiction, 110*(11), 1699–1704.

Choi, K., Fabian, L., Mottey, N., Corbett, A., & Forster, J. (2012). Young adults' favorable perceptions of snus, dissolvable tobacco products, and electronic cigarettes: Findings from a focus group study. *American Journal of Public Health, 102*(11), 2088–2093.

Chu, K. H., Allem, J. P., Cruz, T. B., & Unger, J. B. (2016). Vaping on Instagram: Cloud chasing, hand checks, and product placement. *Tobacco Control, 26*(5), 575–578.

Etter, J. F., Zäther, E., & Svensson, S. (2013). Analysis of refill liquids for electronic cigarettes. *Addiction, 108*(9), 1671–1679.

Food and Drug Administration Statement from FDA Commissioner Scott Gottlieb, M.D., on advancing new policies aimed at preventing youth access to, and appeal of, flavored tobacco products, including e-cigarettes and cigars. From https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm633291.htm, Accessed date: 19 March 2019.

Galstyan, E., Galimov, A., & Sussman, S. (2019). Commentary: The emergence of pod mods at vape shops. *Evaluation & the Health Professions, 42*(1), 118–124.

Goniewicz, M. L., Hajek, P., & McRobbie, H. (2014). Nicotine content of electronic cigarettes, its release in vapour and its consistency across batches: Regulatory implications. *Addiction, 109*(3), 500–507.

Goniewicz, M. L., Kuma, T., Gawron, M., Knysak, J., & Kosmider, L. (2013). Nicotine levels in electronic cigarettes. *Nicotine & Tobacco Research, 15*(1), 158–166.

Kavuluru, R., Han, S., & Hahn, E. J. (2019). On the popularity of the USB flash drive-shaped electronic cigarette Juul. *Tobacco Control, 28*(1), 110–112.

Knapp, A. A., Lee, D. C., Borodovsky, J. T., Auty, S. G., Gabrielli, J., & Budney, A. J. (2019). Emerging trends in cannabis administration among adolescent cannabis users. *The Journal of Adolescent Health, 64*(4), 487–493.

Laestadius, L. I., Wahl, M. M., Pokhrel, P., & Cho, Y. I. (2019). From Apple to Werewolf: A content analysis of marketing for e-liquids on Instagram. *Addictive Behaviors, 91*, 119–127.

Lee, D. C., Crosier, B. S., Borodovsky, J. T., Sargent, J. D., & Budney, A. J. (2016). Online survey characterizing vaporizer use among cannabis users. *Drug and Alcohol Dependence, 159*, 227–233.

Marynak, K. L., Gammon, D. G., Rogers, T., Coats, E. M., Singh, T., & King, B. A. (2017). Sales of nicotine-containing electronic cigarette products: United States, 2015. *American Journal of Public Health, 107*(5), 702–705.

McKelvey, K., Baiocchi, M., Ramamurthi, D., McLaughlin, S., & Halpern-Felsher, B. (2019). Youth say ads for flavored e-liquids are for them. *Addictive Behaviors, 91*, 164–170.

Morean, M. E., Lipshie, N., Josephson, M., & Foster, D. (2017). Predictors of adult e-cigarette users vaporizing cannabis using e-cigarettes and vape-pens. *Substance Use & Misuse, 52*(8), 974–981.

Pepper, J. K., Ribisl, K. M., & Brewer, N. T. (2016). Adolescents' interest in trying flavoured e-cigarettes. *Tobacco Control, 25*(Suppl. 2), ii62–6.

Perrin, A., & Anderson, M. (2018). *Share of U.S. adults using social media, including Facebook, is mostly unchanged since 2018.* From https://www.pewresearch.org/fact-tank/2019/04/10/share-of-u-s-adults-using-social-media-including-facebook-is-mostly-unchanged-since-2018/, Accessed date: 5 August 2019.

Soule, E. K., Lopez, A. A., Guy, M. C., & Cobb, C. O. (2016). Reasons for using flavored liquids among electronic cigarette users: A concept mapping study. *Drug and Alcohol Dependence, 166*, 168–176.

Sussman, S., Baezconde-Garbanati, L., Garcia, R., Barker, D. C., Samet, J. M., Leventhal, A., & Unger, J. B. (2016). Commentary: Forces that drive the vape shop industry and implications for the health professions. *Evaluation & the Health Professions, 39*(3), 379–388.

Talih, S., Balhas, Z., Salman, R., El-Hage, R., Karaoghlanian, N., El-Hellani, A., ... Shihadeh, A. (2017). Transport phenomena governing nicotine emissions from electronic cigarettes: Model formulation and experimental investigation. *Aerosol Science and Technology, 51*(1), 1–11.

Vasiljevic, M., Petrescu, D. C., & Marteau, T. M. (2016). Impact of advertisements promoting candy-like flavoured e-cigarettes on appeal of tobacco smoking among children: An experimental study. *Tobacco Control, 25*(e2), e107–e112.

Zare, S., Nemati, M., & Zheng, Y. (2018 Mar 15). A systematic review of consumer preference for e-cigarette attributes: Flavor, nicotine strength, and type. *PLoS One, 13*(3), e0194145.

Zhan, Y., Liu, R., Li, Q., Leischow, S. J., & Zeng, D. D. (2017). Identifying topics for e-cigarette user-generated contents: A case study from multiple social media platforms. *Journal of Medical Internet Research, 19*(1), e24.

Zhu, S. H., Sun, J. Y., Bonnevie, E., Cummins, S. E., Gamst, A., Yin, L., & Lee, M. (2014). Four hundred and sixty brands of e-cigarettes and counting: Implications for product regulation. *Tobacco Control, 23*(Suppl. 3), iii3–9.