How does Social Media Exposure and Engagement Influence College Students' Use of ENDS Products? A Cross-lagged Longitudinal Study

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Abstract

Electronic nicotine delivery systems (ENDS) products have been marketed heavily on social media throughout the past years, which exerts great influence on young adults' ENDS use. Despite scholars' pioneering efforts in investigating the influence of tobacco and nicotine products marketing on young adults' vaping behavior, scholarly attention has been paid primarily to passive exposure to rather than active engagement with the information on social media. In addition, the majority of existing research has been cross-sectional or focused on the unidirectional path from marketing information to behavior. To extend previous research in tobacco regulatory science on new media, we examined the bidirectional associations between self-reported exposure to and engagement with tobacco and nicotine products messaging on social media, and subsequent use of ENDS products one year later among a large, diverse sample of young adults. Results from cross-lagged panel analyses indicated that pro-tobacco/ENDS engagement and advertising exposure elevated risk whereas anti-tobacco/ENDS engagement decreased risk for the subsequent use of ENDS products one year later. On the other hand, the use of ENDS products positively predicted both pro- and anti-tobacco/ENDS engagement one year later. Findings provide empirical support for the reasoned action approach and the confirmation bias rooted in cognitive dissonance theory through rigorous longitudinal examination. Our findings not only point to the imperativeness of and offer guidance for regulating marketing information on social media, but also suggest social media as a promising platform to prevent young adults from initiating ENDS product use.

Keywords

electronic nicotine delivery systems; vaping; young adults; social media; cross-lagged analysis

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Rapidly growing marketing of and media attention to electronic nicotine delivery systems (ENDS) devices— including electronic cigarettes (e-cigarettes), vape pens, juul/pod vapes, e-hookah, or mods— have pervaded the public communication environment throughout the

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past years (e.g., Cruz et al., 2019). Tobacco and nicotine products— which include ENDS products with nicotine cartridges/pods and/or e-liquid/e-juice, as well as other tobacco products including cigarettes, smokeless tobacco, hookah, and cigars (i.e., large cigars, cigarillos, and/or little filtered cigars)— have been marketed heavily via not only traditional media (e.g., television, radio, magazines), but also social media (e.g., Luo et al., 2014; Paek et al., 2014; Huang et al., 2014). Specifically, recent years have witnessed declines in advertising on traditional venues but a shift towards promotion on social media (Ali et al., 2020). Young adults, as heavy social media users (Pew Research Center, 2019), are particularly vulnerable to the persuasive advertising messages because they lack the cognitive competence to protect themselves from meticulously crafted commercials and may not be able to recognize their selling intent (e.g., Biener & Albers, 2004).

The use of ENDS products by young adults has substantially increased in the last few years (Truth Initiative, 2018), which is related to exposure to and engagement with the promotional messages accessible on social media. *Exposure* refers to individual's routine and accidental acquisition of information that has not been actively sought (Niederdeppe et al., 2007), whereas *engagement* is individuals' active interaction with the information, such as posting or responding to ENDS-related content on social media (Soneji et al., 2017; Unger et al., 2018). Not only have young adults been heavily exposed to advertising of tobacco and nicotine products, but frequently engaged in such content on social media, such as following or liking a tobacco/ENDS brand, posting a link to a vaping product, and commenting on the use of ENDS products (Chen-Sankey et al., 2019; Clendennen et al., 2020; Liu et al., 2020; Pokhrel et al., 2018; Sawdey et al., 2017; Soneji et al., 2018). In turn, exposure to and engagement with tobacco- and ENDS-related messages on social media, which are predominantly promotional (Kim et al., 2015; Luo et al., 2014; McCausland et al., 2019), have been found to significantly increase the likelihood of using tobacco and nicotine products (Pokhrel et al., 2018; Sawdey et al., 2017; Soneji et al., 2018).

Despite scholars' pioneering efforts in investigating the influence of tobacco and nicotine products marketing on young adults' vaping behavior, scholarly attention has been paid primarily to passive exposure to rather than active engagement with the information on social media, with particularly limited research examining how engagement with tobacco and nicotine products information of opposite valence would exert a differential impact on ENDS use. In addition, the majority of existing research has been cross-sectional or focused on the unidirectional path from marketing information to behavior, and few studies specified a non-recursive model by considering the possible feedback loop from ENDS use to tobacco and nicotine products marketing exposure and engagement on social media. Such conceptual and methodological limitations prevent us from developing a comprehensive understanding of how exposure to and engagement with tobacco and nicotine products information is associated with vaping behavior over time among vulnerable populations, such as young adults.

To fill the gap in the literature and to inform the Food and Drug Administration (FDA) about the nature of the associations between tobacco and nicotine advertising and young adults' ENDS use, we conducted a two-wave cross-lagged analysis, with a lag of one year between two waves to assess the bidirectional associations between tobacco advertising on social

media and young adults' ENDS use. In particular, we examined if social media exposure to and engagement with tobacco and nicotine advertisements was associated with subsequent increases in ENDS use one year later. We simultaneously tested the opposite direction of effects, if ENDS use was associated with subsequent increases in social media exposure to and engagement with tobacco and nicotine advertisements one year later. Equipped with better understanding about the aforementioned bidirectional associations, the regulation of ENDS marketing information is expected to be more targeted and effective.

ENDS Products Use among Young Adults

Recently released data indicate alarming trends in the use of ENDS products among young adults in the United States (U.S.). According to the 2014–2018 National Health Interview Survey with a nationally representative sample, young adults reported increased prevalence of current ENDS, with a 46.2% increase from 2017 (5.2%) to 2018 (7.6%; Dai & Leventhal, 2019). The current use of ENDS products by young adults surpassed that of older adults in 2014, with the prevalence of young adults' past 30-day use of ENDS (13.6%) more than twice that of adults' 25 years of age and older (5.7%; US Department of Health and Human Services, 2016). The high prevalence and increasing rates of ENDS use among young adults were identified by the FDA (2018) as reaching an epidemic proportion of growth. Despite the controversial and inconclusive scientific evidence about the potential reduced harm and cessation-related claims of ENDS, vaping among young adults is of particular public health concern, because of its potential to serve as a "gateway" to initiate combustible cigarette smoking (NASEM, 2018; Primack et al., 2018). The exposure to nicotine, often contained in ENDS products, is also harmful to the brain development of young adults (US Department of Health & Human Services, 2016).

Young adults' vaping behavior has been found to be associated with the tobacco and nicotine products information to which they are exposed. Longitudinal evidence showed that both intentional effort to obtain specific ENDS information (also known as "information seeking") and incidental exposure to information without making an active effort (also known as "information scanning") increase the likelihood of young adults' ENDS products use, even after controlling for baseline smoking and vaping status, intention to vape, and demographics (Liu et al., 2020; Yang et al., 2019). Health information exposure influences behaviors through the underlying cognitive mechanisms of (a) enhancing self-efficacy by acquiring new information and skills to conduct the behavior, (b) increasing descriptive norms of the behavior through repeated exposure, and (c) providing a cue to action for conducting the behavior (e.g., Liu et al., 2020; Martino et al., 2018). However, previous research also reports that ENDS use predicts subsequent ENDS marketing exposure (Kreitzberg et al., 2019), indicating that ENDS users may be more likely than their peers to be exposed to tobacco marketing messages. Unfortunately, this previous research combined exposure to marketing from a variety of medium (e.g., television, billboards, and Internet), and did not include a measure of tobacco advertising on social media. Given the ubiquity of social media and that 90% of young adults use and interact with social media every day (Pew Research Center, 2019), it is important to scrutinize how exposure to and engagement with tobacco and nicotine products information present on social media are associated with young adults' vaping behavior longitudinally.

Social Media Exposure to Tobacco and Nicotine Advertising

The prevalence of ENDS use among young adults can be attributed, in part, to the rampant marketing on social media, which are heavily used by young adults. The comparative inexpensiveness and lack of marketing regulation make social media a "wild-west" to promote tobacco and nicotine products (Clark et al., 2016; Jackler et al., 2019). Content analytic studies documented that tobacco and nicotine information is predominantly promotional on social media, including Twitter (Allem et al., 2018; Clark et al., 2016; Huang et al., 2014; Kim et al., 2015), Facebook (Jackler et al., 2019), Instagram (Laestadius, Wahl et al., 2019; Laestadius, Penndorf et al., 2019), and YouTube (Luo et al., 2014; Yang et al., 2018). Such heavy marketing is of particular public health concern, given that the use rates of almost all social media platforms are highest among young adults (Duggan et al., 2015), and online tobacco and nicotine promotional messages are largely targeted to youth and young adults (Grana & ling, 2014; Luo et al., 2014), with widespread sales promotion (Jackler et al., 2019; McCausland et al., 2019).

ENDS advertising on social media has been significantly associated with ENDS products use among youth and young adults (Clendennen et al., 2020; Pokhrel et al., 2018; Sawdey et al., 2017; Trumbo & Kim, 2015). Specifically, cross-sectional evidence indicated that viewing peer posts and advertisements on social media increased the likelihood of both lifetime and current use of ENDS among college students (Pokhrel et al., 2018; Sawdey et al., 2017). Similar findings were obtained in longitudinal studies, which reported that young adults exposed to tobacco or ENDS marketing on social media were more susceptible to the use of tobacco five months later (Depue et al., 2015) or ENDS at one-year follow-up (Chen-Sankey et al., 2019). According to the reasoned action approach (Fishbein & Ajzen, 2011), young adults could be misled by the advertising information they receive, which influences their attitudes and normative beliefs towards the use of ENDS products. For instance, previous studies found that young adults who are exposed to more tobacco and nicotine marketing information perceived less harm (e.g., lower addictiveness; Trumbo & Kim, 2015) and more benefits (e.g., positive sensory experience; Pokhrel et al., 2018) of using them, which positively predicted their intention and behavior of using ENDS products. Based on theory and previous literature, we hypothesized that:

H1: Young adults' exposure to tobacco and nicotine advertising on social media will positively predict their subsequent use of ENDS products one year later.

Compared to the effect of tobacco and nicotine products information on subsequent use of ENDS products, less scholarly attention has been paid to how vaping behavior may influence subsequent exposure to related information. Kreitzberg and colleagues (2019) reported a bi-directional relationship between self-reported exposure to ENDS marketing and ENDS use among college students using a longitudinal survey design; specifically, not only did ENDS marketing exposure predict subsequent behavior, but the use of ENDS products also increased the likelihood of being exposed to ENDS marketing. Such an effect could be explained by the theories of selective exposure (Zillmann & Bryant, 1985) rooted in cognitive dissonance theory (Festinger, 1957), which argues that individuals tend to increase their likelihood to access information that is in line with and supportive of

their behaviors to decrease cognitive dissonance. In this case, young adults who use ENDS products may be more likely to subscribe to ENDS brands pages or "friend" with other ENDS users on social media, which increase these young adults' chances of being exposed to tobacco and nicotine products marketing information. Based on theory and existing evidence, we also hypothesized that:

H2: Young adults' use of ENDS products will positively predict their subsequent exposure to tobacco and nicotine advertising on social media one year later.

Social Media Engagement with Tobacco and Nicotine Information

Besides the passive exposure of information, young adults, who use all popular social networking platforms more than older adults (Perrin & Anderson, 2019), are also actively engaged with tobacco and nicotine products marketing on social media. For instance, one-third (32%) of the young adults who have a Twitter account have posted at least one tobacco-related tweet, with an average of 2.8 tweets posted (Unger et al., 2018). In another study, 10% of college students reported posting or mentioning ENDS on social media platforms (i.e., Facebook, Twitter, and Instagram), whereas 43.8% viewed at least one post or mention from their "friends" on these platforms in the past six months (Sawdey et al., 2017).

Previous studies have documented significant associations between social media engagement with tobacco and nicotine information and the use of these products. Based on nationally representative samples from the Population Assessment of Tobacco and Health (PATH) Study, approximately 12% of adolescents are engaged in online tobacco marketing – such as sending or receiving a link or information about a tobacco company to others, receiving discount coupons, and liking or following a tobacco company on social media, and they reported not only higher susceptibility to the use of any tobacco product (Soneji et al., 2017), but also increased frequency of use, progression to poly-product use, and lower likelihood of cessation (Soneji et al., 2018). In the same vein, pro-tobacco engagement also led to increased risk of use of all tobacco products among college students (Clendennen et al., 2020). Cross-sectional research indicated that young people who have ever tried or are currently using ENDS products are also more likely to post tobacco and nicotine-related content (e.g., videos or pictures of smoke tricks) and write or respond to posts (Hébert et al., 2017). Given that purchase links (e.g., "shop now" button), sales promotions and images of tobacco products could be particularly problematic to trigger initiation and substantiate daily use (Jackler et al., 2019), we proposed:

H3: Young adults' engagement with promotional (pro-) tobacco and nicotine information on social media will positively predict subsequent use of ENDS products one year later.

Introduced as an alternative nicotine delivery device to the U.S. market in 2007, ENDS products have been surrounded with uncertainty in terms of their potential risks and benefits to health, and the related scientific inquiry remains in its early stages (Bradac, 2001). Although some organizations acknowledge the lack of sufficient scientific evidence, others frame ENDS products in a positive or negative light by selectively emphasizing their

potential risks (e.g., long-term health effects, gateway to poly-use) or relative benefits to combustible cigarettes (e.g., harm reduction, smoking cessation tool; Truth Initiative, 2019), or long-term health effects of second hand vaping (American Academy of Pediatrics, 2015). Despite the promise of ENDS products' reduced harm compared to combustible cigarettes, the long-term scientific evidence regarding the efficacy of ENDS products for safe and successful smoking cessation remains inconclusive (e.g., Du et al., 2020; Kalkhoran & Glantz, 2016).

Such scientific uncertainty about ENDS products leads to ambivalent public views and makes the public communication environment on social media a mixture of positive and negative information about tobacco and nicotine products (Kim et al., 2020). For instance, 60.9% of posts on Reddit described negative perceptions while 19.9% reported positive perceptions of youth using JUUL, the most prevalent ENDS brand (Brett et al., 2019). Participants also reported being exposed to (Ilakkuvan, 2018; Lee et al., 2020; Yang et al., 2019) and engaged with (Clendennen et al., 2020; Unger et al., 2018) both pro- and anti-tobacco/ENDS information. With the majority of scholarly attention paid to the effects of engaging in tobacco/ENDS marketing on social media, the empirical evidence documenting the relationship between anti-tobacco/ENDS social media engagement on product use is limited (Clendennen et al., 2020; Unger et al., 2018). Despite limited evidence, we maintain that engagement with anti-tobacco and nicotine information would enhance young adults' risk perceptions of using ENDS products, and therefore hypothesized:

H4: Young adults' engagement with anti-tobacco and nicotine information on social media will negatively predict subsequent use of ENDS products one year later.

According to selective exposure, which is a defensive bias that drives people to favor information that supports their behaviors (Festinger, 1957; Knobloch-Westerwick, 2014), young adults using ENDS products not only have more possibility to be exposed to tobacco and nicotine products information, but are also more likely to attend to and engage with that information. Confirmation bias, often used in conjunction with selective exposure, further explains individuals' processing and interaction with information (Jonas et al., 2001).

Specifically, people have a tendency to attend to, interpret and use information that confirms their behaviors, while ignoring disconfirming information (Klayman & Ha, 1987; Jonas et al., 2001), which has been empirically supported in previous studies focusing on ENDS products (Hébert et al., 2017). Following such logic, we hypothesized that young adults who use ENDS products are more likely to engage with pro-tobacco and nicotine information on social media, which is supportive of their behavior, and less likely to engage with anti-tobacco and nicotine information, which contradicts their behavior and may cause cognitive dissonance. Thus:

H5: Young adults' use of ENDS products will a) positively predict their subsequent engagement with pro-tobacco and nicotine information but b) negatively predict their subsequent engagement with anti-tobacco and nicotine information on social media one year later.

Method

Participants

Participants are 4,268 young adults participating in the Marketing and Promotions across Colleges in Texas (M-PACT) Project. Project M-PACT is a five-year longitudinal study that recruited a cohort of students in fall 2014 from 24 two- and four-year (n =12 two- and 12 four-year) Texas colleges in the five counties surrounding the four largest metropolitan areas in Texas (Austin, Dallas/Fort Worth, Houston, and San Antonio). To be eligible, participants were required be 18–29 years of age and full- or part-time degree- or certificate-seeking undergraduates at a participating four-year college or enrolled in a vocational program at a two-year college. Eligible students who agreed to participate completed an informed consent and an online survey. For the purposes of the present study, data were derived from the Spring, 2017 and Spring, 2018 surveys given that Spring 2017 was the first wave in which questions regarding social media exposure and engagement were included. Hereafter Spring 2017 is referred to as baseline/T1 and Spring 2018 as T2. 80% the original M-PACT cohort (N = 5,482) participated in Spring 2017. The study protocol was approved by the university's Institutional Review Board.

Measures

ENDS Advertising Exposure on Social Media.—Participants were asked to report how often they saw any advertisements for any tobacco and nicotine products on seven social network sites (i.e., Facebook, Instagram, Twitter, Snapchat, YouTube, Pinterest, and Reddit) during the past 30 days at T1 and T2. All questions were measured on a 5-point Likert scale (0 = *never*, 4 = *very frequently*), which were recoded into dichotomous variables with 0 = *never exposed* and 1 = *ever exposed* given the lack of variance in terms of the frequency of advertising exposure on each individual social media platform. Given that the percentage of participants who have ever been exposed to tobacco/ENDS advertising on specific social media range from 4.8% (Pinterest, T1) to 14.9% (Facebook, T1), we further aggregated these variables to be tobacco/ENDS advertising exposure on any social media (0 = *never exposed* and 1 = *ever exposed*).

Engagement with Tobacco Information on Social Media.—Both pro- and anti-engagement with tobacco and nicotine information were measured by three items at T1 and T2, asking participants to rate how often they were engaged with messaging about any tobacco and nicotine products – i.e., (a) posting links, (b) posting thoughts or comments, and (c) encouraging or discouraging other people from using a tobacco and nicotine product – on social media (Clendennen et al., 2020; Hébert et al., 2017). Answers were coded on a 5-point Likert scale (1 = *never*, 5 = *very frequently*). The three items demonstrated satisfactory reliability in Cronbach's a for both pro- (a = .83 at T1, a = .85 at T2) and anti-tobacco/ENDS engagement (a = .76 at T1, a = .78 at T2), and were averaged to create a composite score, with higher scores reflecting higher level of engagement.

Current Use of ENDS Products.—Current use of ENDS devices was assessed at T1 and T2 by asking "During the past 30 days, have you used any ENDS product (i.e., an e-cigarette, vape pen, or e-hookah), even one or two puffs, as intended (i.e. with nicotine

cartridges/pods and/or e-liquid/e-juice)." Responses were recorded on a dichotomous scale (0 = *no*, 1= *yes*).

Other confounders.—All models were adjusted for potential confounders, including participants' baseline age, sex (male and female), and race/ethnicity (non-Hispanic white, Hispanic/Latino, Asian, African American/black), use of other tobacco products including cigarettes, smokeless tobacco, hookah, and cigars (i.e., large cigars, cigarillos, and/or little filtered cigars), and sensation seeking assessed using the Brief Sensation Seeking Scale (BSSS; Stephenson et al., 2003). We also measured the baseline number of tobacco or ENDS products that had ever been used by participants' close friends and people living in their household as covariates (see Table 1 for details).

Data analyses

Descriptive statistics, including means (*Ms*) and standard deviations (*SDs*) of all study variables are reported in Table 1. A longitudinal cross-lagged model using MPlus 8.1 was used to simultaneously examine the bi-directional associations between social media exposure to and engagement with tobacco/ENDS information, and ENDS use across the two study waves. That is, we included (a) cross-lagged paths from T1 social media exposure to and engagement with tobacco/ENDS information to T2 ENDS use, (b) cross-lagged paths from T1 ENDS use to T2 social media exposure to and engagement with tobacco/ENDS information, and (c) stability paths from all T1 variables to the same T2 variables. We also covaried each of the variables within T1 and T2 respectively. Finally, we controlled for the T1 confounding variables by including them as exogenous variables in the model. See Figure 1 for the model illustration.

Given that current use of ENDS products and tobacco/ENDS advertising exposure on social media as endogenous variables were dichotomous, the hypothesized path model (see Figure 1) was estimated using the weighted least squares mean and variance adjusted (WLSMV) estimator, which is robust to normality of observed variables and accommodates missing data for endogenous variables (Li, 2014). However, a small portion of participants (6.4%) were missing data on the exogenous covariates and were removed from analyses, resulting in a final sample size of 4,268.[1] Model fit was examined using the following indices and criteria: nonsignificant Chi-square test, values greater than .90 for comparative fit index (CFI) and Tucker-Lewis index (TLI) along with values smaller than .05 for the standardized root mean square residual (SRMR) and root mean square of approximation (RMSEA) (Browne & Cudeck, 1993; Hu & Bentler, 1998; McDonald & Ho, 2002).

Results

Descriptive Data

As shown in Table 1, participants were aged between 20 to 32 years (*M* = 23.28, *SD* = 2.30) at T1, with 64.8% of them being female. The majority of participants self-reported as

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[1]In total, 4,561 students participated at T1 (spring 2017). Among these participants, we removed 116 cases, who had at least one missing value on exogenous variables, which can not be accomodated by the WLSMV estimator. Therefore, the final sample size for cross-lagged analysis is 4,268.

non-Hispanic White (35.6%) or Hispanic (30.8%), followed by Asian (18.3%) and African American (7.8%). At baseline, 76.7% and 39.0% of the participants had at least one close friend or one person living in the same household respectively, who used at least one tobacco product. The percentage of participants who were current users of at least one ENDS product increased from 9.2% at T1 to 12.2% at T2, and 24.2% of participants used at least one other tobacco product (i.e., cigarettes, smokeless tobacco, hookah, cigars) at T1.

In regards to social media exposure and engagement, 20.6% and 22.6% of participants had been exposed to at least one advertisement for tobacco and nicotine products during the past 30 days at T1 and T2 respectively. The prevalence of anti-tobacco/ENDS engagement (18.8% at T1, 18.1% at T2) was higher than pro-tobacco/ENDS engagement (6.8% at T1, 7.0% at T2) at both study waves. However, the frequency of engagement with both pro- (M = 1.06 at T1, M = 1.07 at T2) and anti- tobacco/ENDS information (M = 1.17 at T1, M = 1.17 at T2), measured on a 5-point Likert scale, was low.[2] More details can be found in Table 1.

Cross-lagged Analyses

The hypothesized model fit the data very well ($\chi^2(46) = 499.23$, $p < .001$; RMSEA = .048 [90%CI: .044- .052], CFI = .96, TLI = .91, SRMR = .068).[3] Therefore, we proceeded with examining the path coefficients to test the hypotheses. The cross-lagged path from T1 tobacco/ENDS advertising exposure to subsequent T2 current ENDS use was significant ($p < .01$), which supported H1. However, H2 was not supported given the marginally significant path from T1 current ENDS use to subsequent T2 exposure to tobacco/ENDS advertising ($p = .06$). Since T2 ENDS use was predicted positively by T1 pro-tobacco/ENDS engagement ($p < .01$) and negatively by T1 anti-tobacco/ENDS engagement ($p < .01$), both H3 and H4 were supported. Regarding the opposite direction of associations, T1 current ENDS use significantly predicted subsequent T2 pro-tobacco/ENDS engagement on social media ($p < .001$). Although we also found that T1 current ENDS use predicted subsequent T2 anti-tobacco/ENDS engagement ($p < .001$), the association was positive. Thus, H5a was supported, while H5b was not. It is important to note that these cross-lagged effects were significant, even after controlling for statistically significant covariates, and for the stability of ENDS use and each exposure and engagement variable across the one year period.

Discussion

To extend previous research in tobacco regulatory science on new media, we examined the bidirectional associations between self-reported exposure to and engagement with tobacco and nicotine products messaging on social media, and subsequent use of ENDS products one year later among a large, diverse sample of young adults. The results supported the hypotheses, indicating that pro-tobacco/ENDS engagement and advertising exposure elevates risk whereas anti-tobacco/ENDS engagement decreases risk for current use of

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[2]According to Li (2014), the WLSMV estimation implemented in the current study is robust to non-normal data because it "make[s] no distributional assumption germane to the shape of observed variables" (p.29). Therefore, the low mean and non-normality of tobacco/ENDS social media exposure and engagement variables are unlikely to influence the robustness of the results.
[3]Chi-square value is almost always statistically significant when the sample size is over 400 (Bentler & Bonett, 1980; Kenny, 2020). Therefore, we decided the model fit in the current study based on other indices.

ENDS products. In addition, the use of ENDS products positively predicted both pro- and anti-tobacco/ENDS engagement. Our findings extend existing literature on the associations between social media and ENDS products use among young adults, and provide important insights for tobacco regulatory science.

Consistent with existing literature, we found that pro-ENDS engagement and advertising exposure on social media positively predicted subsequent ENDS use (Chen-Sankey et al., 2019; Clendennen et al., 2020; Hébert et al., 2017; Pokhrel et al., 2018; Sawdey et al., 2017). Exposure to ENDS advertising, which increases positive "smoking" and sensory experiences, had a direct effect on young adults' ENDS use (Pokhrel et al., 2018). According to the reasoned action approach (Fishbein & Ajzen, 2011), such exposure could also reduce young adults' risk beliefs and enhance their positive attitudes towards using ENDS products, which lead to vaping behavior. In the same vein, engaging with pro-ENDS information— such as posting links to pro-ENDS product websites/stories/articles, posting thoughts or comments on the positive aspects of ENDS use, and encouraging other people to use ENDS products— had a positive effect on ENDS use too. This finding is supported by the confirmation bias and cognitive dissonance theory, since pro-ENDS engagement behaviors will reduce young adults' psychological disequilibrium through confirming and validating their own vaping behavior (Festinger, 1957; Jonas et al., 2001; Knobloch-Westerwick, 2014).

On the other hand, this study is the first to document a negative effect of anti-tobacco/ENDS social media engagement on the use of ENDS products, which differed from previous null findings (Clendennen et al., 2020; Unger et al., 2018). Specifically, Unger et al. (2018) reported a null association between posting neutral/negative tobacco messages on Twitter and tobacco use, and Clendennen et al.'s (2020) longitudinal study found college students' engagement with anti-tobacco content on social media predicted higher likelihood of using cigars and hookah but not ENDS. Such discrepancies may be a result of varying assessments of social media. For example, Unger et al. (2018) measured one aspect of social media engagement (i.e., posting tobacco messages) and lumped neutral and negative messages together, whereas in the present study, we assessed multiple engagement practices (e.g., posting ENDS products links/thoughts/comments, and encouraging other people to use ENDS products) and did not consider neutral messages. Given limited empirical evidence examining the association between anti-ENDS social media engagement and vaping behavior, more research is needed.

Several noteworthy findings were obtained by analyzing the opposite direction of effects, from young adults' current ENDS use to their social media exposure to and engagement with tobacco/ENDS information one year later. In line with a previous study (Hébert et al., 2017) and the confirmation bias literature (Klayman & Ha, 1987; Jonas et al., 2001), the use of ENDS products predicted pro-tobacco/ENDS engagement, which indicates that young adult ENDS users had the tendency to validate their behaviors by broadcasting positive aspects of ENDS products and advocating for ENDS use. However, it was counter-intuitive that ENDS users were more likely than non-ENDS users to engage in anti-tobacco/ENDS messages on social media. Since ENDS products have been widely used as a smoking cessation tool (Kalkhoran & Glantz, 2016), it is plausible that this group of users post

anti-tobacco messages or comments on social media to discourage other people from smoking combustible cigarettes. Future research is encouraged to validate this speculation by differentiating social media engagement with tobacco and nicotine information. Finally, individuals are theorized to change their social networks based on their vaping behaviors, which increases their likelihood to socialize with other vapers and therefore be exposed to ENDS marketing, referred to as the *selection* process according to the social network theory (Christakis & Fowler, 2007). However, we observed a marginally significant effect of vaping behavior on tobacco/ENDS exposure, which might be explained by ENDS users' desensitization to tobacco and nicotine products. Since users of ENDS products report higher frequency of exposure to tobacco and nicotine advertising compared to non-users, such information may be less salient and memorable to them. Further research will be needed to clarify this relationship by measuring exposure to specific products on social media.

Theoretical and regulatory implications

The most noteworthy finding of our study is that after adjusting for various significant covariates as well as stability paths for all study variables, we still observed that young adults' exposure to ENDS marketing and pro-engagement with nicotine and tobacco products on social media significantly predicted their use of ENDS products one year later, above and beyond the reversed effects. Such effects are particularly concerning for young adults, who, as heaviest users among all age groups, spend a median of three hours per day on social media (Metev, 2020; Pew Research Center, 2019). The enormous amount of promotional ENDS information and the easy accessibility of such information on social media render young adults particularly vulnerable to being misled by the heavy marketing, who will further overestimate the benefits or underestimate the harms, which will lead to the initiation of or continued use of ENDS products (Pokhrel et al., 2018). Albeit concerning, social media is still considered a "wild-west" to promote tobacco and nicotine products with minimal regulation (Clark et al., 2016; Jackler et al., 2018). However, the regulations of marketing tobacco and nicotine products, once implemented, were found effective in reducing smokers' awareness of pro-tobacco cues and smoking behaviors (Kasza et al., 2011). Therefore, we point to the necessity and imperativeness of regulating marketing information on social media, such as prohibiting or limiting the promotion on ENDS brand pages, making the content only visible to adults 25 years or older, including additional application and verification procedures to access the promotional messages, or requiring warning label next to the promotion.

Besides the regulation of tobacco and nicotine marketing, our findings also suggested social media as a promising platform that health communication scholars and practitioners could take advantage of to disseminate anti-tobacco/ENDS messages, and ultimately to prevent young adults from initiating ENDS product use. Despite the paucity of ENDS interventions, previous social-media-based anti-tobacco interventions and campaigns were effective in promoting quitting attempts and abstinence among young adult smokers (Baskerville et al., 2015; Ramo et al., 2015). Furthermore, the recent "Real Cost" campaign addressing the rising epidemic of ENDS use among young adults conducted by the FDA was delivered on a variety of social media channels, such as YouTube, Facebook and Instagram (Zeller, 2019).

Although further empirical evidence is needed to confirm the effectiveness of anti-ENDS interventions and campaigns on social media, previous studies along with our finding that anti-engagement with tobacco and nicotine products reduced subsequent likelihood of using ENDS products provide support for social media in disseminating anti-ENDS to young adults.

Last but not least, this is the first study to examine the bidirectional associations between social media engagement and ENDS use over time. That young adults who use ENDS products are more likely to be engaged with pro-tobacco/ENDS information offered empirical support for the confirmation bias rooted in cognitive dissonance theory, suggesting that individuals are biased towards attending to, processing and engaging in attitude-consistent messages to maintain the cognitive equilibrium (Festinger, 1957; Knobloch-Westerwick, 2014; Zhao et al., 2020). By posting links related to tobacco/ENDS brand websites, commenting favorably about positive aspects of tobacco and nicotine products, and encouraging other people to jump on the bandwagon of ENDS use further confirmed their beliefs and behavior of using ENDS products (Knobloch-Westerwick, 2014). However, such pro-engagement practices on social media further increased the likelihood of their social networks' exposure to ENDS marketing, which is a more concerning health communication issue. Given the scarcity of investigations focusing on the impact of confirmation bias on health information engagement (Zhao et al., 2020), the current study shed theoretical light on this process through rigorous longitudinal examination.

Limitations and future research

Our study is not without limitations. First, the participants included in the current study were recruited in Texas and thus are not nationally representative. Although our sample is racially/ethnically diverse and our findings echo previous research using different samples (e.g., Chen-Sankey et al., 2019; Hébert et al., 2017; Soneji et al., 2017, 2018), we encourage future research to generalize our findings to other samples. Second, as an exploratory study, we did not differentiate between combustible tobacco and nicotine products in measuring participants' exposure and engagement on social media, which limited our interpretability of the counter-intuitive findings. Relatedly, our measures of all variables were based on self-reported responses, which have been widely used in health communication research regarding tobacco and nicotine products (e.g., Hébert et al., 2017; Liu et al., 2020; Pokhrel et al., 2018; Yang et al., 2019), but are subject to recall and desirability bias. Finally, the items we used to measure participants' social media engagement may not be a comprehensive capture of this construct. More questions (e.g., posting pictures/videos of ENDS products, playing online games related to an ENDS brand) are potentially possible to expand this spectrum or increase the granularity of measuring engagement with ENDS information on social media (Hébert et al., 2017; Soneji et al., 2017). Finally, to avoid overcontrolling and to focus on the bidirectional associations between tobacco advertising on social media and young adults' ENDS use, we did not control for exposure to tobacco or ENDS on other media. Future scholars could expand this line of research, by (a) taking a closer examination of the nuances between exposure to information about different tobacco products on social media, (b) measuring engagement with a more comprehensive scale, and

(c) controlling for young adults' exposure to tobacco or ENDS on other media to understand the aforementioned associations over and above marketing via other media.

Conclusion

Despite the study limitations, our study obtained two major findings. First, we generated empirical evidence of how young adults' use of ENDS products influence their subsequent exposure to and engagement with tobacco and nicotine products information in a longitudinal manner, which has been understudied compared to the reverse relationship. Second, even after adjusting for baseline vaping behavior and the feedback loop from vaping behavior to information exposure and engagement, we still observed that young adults' exposure to tobacco/ENDS marketing and engagement in pro-tobacco/ENDS information increased their likelihood of using ENDS products, whereas engagement in anti-tobacco/ENDS information reduced their probability of vaping. The findings not only point to the necessity of regulating promotional and marketing information about nicotine and tobacco products on social media, but also suggest social media as a potential cost-efficient platform to disseminate anti-tobacco campaign messages to prevent young adults from using ENDS products.

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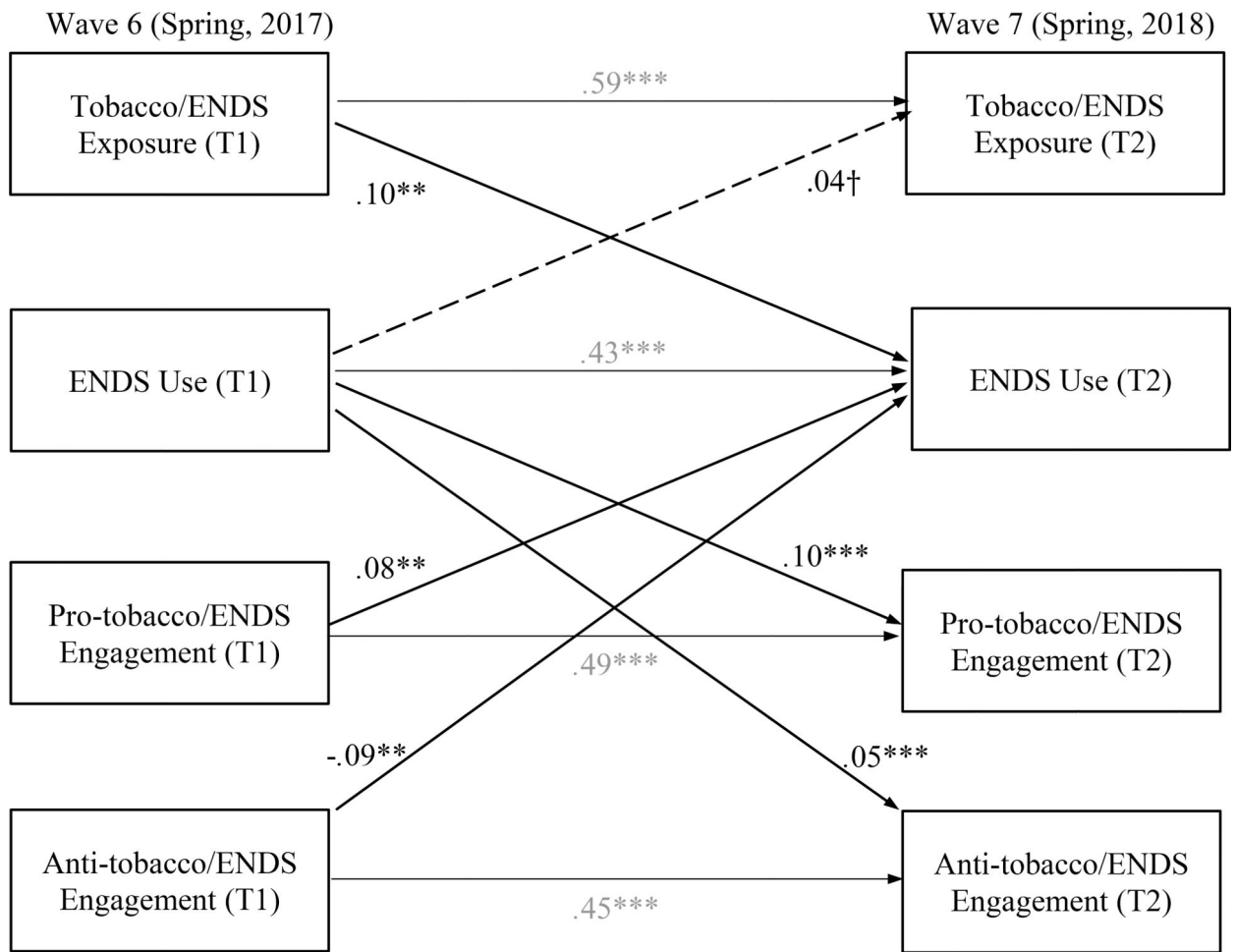
Figure 1. Cross-lagged model examining bidirectional associations between tobacco and ENDS exposure and engagement on social media and ENDS use among young adults (N = 4,268)

Note. Nonsignificant paths are represented by a dashed line. The coefficients presented are standardized. † $p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$. T1 = Wave 6 or baseline, T2 = Wave 7. For visual clarity, all covariates (i.e., age, gender, race/ethnicity, statuses of using ENDS and other tobacco products, sensation seeking, number of close friends who use combustible cigarettes and/or vape, and household vaping status) at T1 are included as control variables, but not shown in this figure.

Table 1

Demographics for the Full Sample (N = 4,268)

Variables	Wave 6/Baseline (T1)	Wave 7 (T2)	Test Statistics
Age (years; $M \pm SD$)	23.28 ± 2.30		
Female (%)	64.8		
Race/ethnicity (%)			
Non-Hispanic White	35.6		
Non-Hispanic African American	7.8		
Hispanic	30.8		
Asian	18.3		
Other	7.5		
Current use of ENDS products (%)	9.2	12.2	$\chi^2(1) = 13.30$ [***]
Current use of tobacco products besides ENDS (Min=0, Max=4; $M \pm SD$)	.33 ± .68		
Number of tobacco/ENDS products used by close friends (Min=0, Max=5; $M \pm SD$)	2.42 ± 1.84		
Number of tobacco/ENDS products used by people living in household (Min=0, Max=5; $M \pm SD$)	1.04 ± 1.68		
Sensation seeking (Min=1, Max=5; $M \pm SD$)	3.14 ± .93		
Exposure to tobacco/ENDS information on social media (%)	20.6	22.6	$\chi^2(1) = 4.97$ [*]
Pro-engagement tobacco/ENDS information on social media (Min=1, Max=5; $M \pm SD$)	1.06 ± .29	1.07 ±.33	$t = -1.46$
Anti-engagement tobacco/ENDS information on social media (Min=1, Max=5; $M \pm SD$)	1.17 ± 43	1.17 ±.46	$t = .00$

Note. The percentage was calculated without including the missing values. Tobacco products are referred to as cigarettes, cigars, hookah, or smokeless tobacco in the current study. Close friends or people living in household who use tobacco products were measured based on the number of tobacco (i.e., cigarettes, cigars, hookah, or smokeless tobacco) and ENDS products that had ever been used by participants' close friends and people living in their household. The last column shows the statistics comparing the mean (*t* statistic) or proportion (χ^2 statistic) of T1 and T2 focal variables. The sample size for wave 7 ranges from 3847 to 3852, and was included in the final model because WLSMV estimator accommodates missing values for endogenous variables, which were measured at T2.

[*]
$p < .05$

[**]
$p < .01$

[***]
$p < .001$.