Cognitive Roadblock Not Gateway: Effects of Visual Vaping Cues on Young Adults' Harm Perceptions

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Objectives: In this study, we experimentally tested 2 hypotheses regarding visual vaping cues in e-cigarette video advertisements on harm perceptions immediately following exposure (T1), and again, 2 weeks later (T2). The cognitive gateway hypothesis predicts that vaping cues will reduce vaping harm perceptions among e-cigarette users at T1, leading to lowered smoking harm perceptions at T2. In contrast, the cognitive roadblock hypothesis predicts that vaping cues will heighten smoking harm perceptions among smokers at T1, leading to increased vaping harm perceptions at T2. **Methods:** We conducted a 2-wave online experiment with 251 smokers or e-cigarette users recruited from students enrolled at a large midwestern university in 2016. Participants were randomized to view: (1) 5 e-cigarette ads containing vaping cues; (2) 5 e-cigarette ads without vaping cues; or (3) 5 bottled drink ads. **Results:** Findings support the cognitive roadblock hypothesis but not the gateway hypothesis. For current smokers, mediating effects of smoking harm perceptions at T1 were supported. **Conclusions:** E-cigarette advertisements with vaping portrayals can increase smokers' vaping harm perceptions indirectly by activating smoking harm perceptions, potentially deterring smokers from switching to a less harmful product.

Key words: visual vaping cue; consumer perceptions; advertising; electronic cigarette (e-cigarette); cognitive gateway/roadblock; young adult
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Electronic cigarettes (e-cigarettes) are battery-powered systems that deliver nicotine by producing an inhaled aerosol instead of smoke.[1,2] Between 2012 and 2015, the number of current smokers who perceived e-cigarette vaping to be equally or more harmful than cigarette smoking increased from 11.7% to 35.1% in the United States (US).[3,4] Research suggests that e-cigarette emissions contain fewer toxicants and pose less physiological harm than cigarette smoking, at least at the individual level,[2,5-7] although longer-term health consequences of e-cigarette use for the population remain unknown.[1,8] Perceived harms of vaping have been assessed with or without reference to combustible cigarettes, and both absolute and relative harm perceptions were found to be predictive of e-cigarette use.[9-11] Because harm perceptions can predict e-cigarettes use,[10,12-14] increased misconception that e-cigarettes are just as or more harmful than combustible tobacco cigarettes may discourage smokers from switching to e-cigarettes to reduce cigarette-attributable morbidities.

One important information source that could affect consumers' harm perceptions is exposure to e-

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cigarette advertising. Unlike combustible cigarettes, in the US e-cigarette advertising is not prohibited on media outlets,[15] and many advertisements explicitly target adolescents and young adults.[16,17] Expenditure on e-cigarette advertising increased from $6.4 million in 2011[18] to $88.1 million in 2014,[19] and exposure to e-cigarette advertisements among young adults increased by 321% from 2011 to 2013.[20] One particular visual cue in e-cigarette advertisements, visual portrayals of vaping that include the hand-to-mouth motion and oral inhaling/exhaling of vapor, has been shown not only to increase the urge to vape, but also to increase the urge to smoke among current smokers.[21-24] Due to the visual similarity between e-cigarette vaping and combustible cigarette smoking, exposure to such visual vaping cues may influence both consumer harm perceptions about vaping and about smoking. However, to date, no studies have tested the effects of exposure to visual vaping cues on harm perceptions. To address this gap in the literature, we conducted a 2-wave longitudinal experiment to test both immediate and delayed effects of exposure to visual vaping cues on perceived harms of vaping and smoking.

Cognitive Gateway versus Roadblock Effects

Potential effects of exposure to visual vaping cues on harm perceptions could have differing implications on population health among never smokers versus smokers. First, based on the gateway hypothesis, a series of steps may lead from exposure to visual vaping cues to e-cigarette use, and ultimately, to smoking combustible cigarettes. For instance, a randomized controlled trial has shown that exposure to e-cigarette advertising can reduce harm perceptions and increase intention to try e-cigarettes among adolescents.[25] These results are consistent with the hypothesis that exposure to e-cigarette advertising may encourage youth who have never smoked to initiate e-cigarette use. E-cigarette experimentation would lead to nicotine dependence, and eventually, progression to smoking combustible cigarettes among youth.[8,26,27] Cross-sectional surveys found that initial e-cigarette use among non-smoking young adults was indeed associated with higher intention to smoke[28,29] and increased smoking behaviors.[30] The association between e-cigarette use and subsequent smoking initiation was supported in a meta-analysis of longitudinal studies.[31] However, a prospective cohort study evaluating bidirectional relationships found evidence that conventional smoking was predictive of subsequent e-cigarette use, but not vice versa.[32] The current study focuses on a cognitive component in the gateway hypothesis, harm perceptions about smoking and vaping that may impact the transition from e-cigarette use to combustible cigarette smoking. Among e-cigarette users who are not current smokers, exposure to visual vaping cues in e-cigarette video advertisements is hypothesized to reduce vaping harm perceptions, which in turn, are expected to lead to reduced smoking harm perceptions. We call this the cognitive gateway hypothesis.

On the other hand, similar to effects on the urge to smoke, visual vaping cues may inadvertently activate existing beliefs about smoking harms among smokers,[33,34] which could increase rather than reduce perceived harms of vaping. We call this the cognitive roadblock hypothesis. Increased harm perception could deter smokers from switching to a less harmful way to obtain nicotine.[35] Some tobacco control researchers stress the potential of e-cigarettes for harm reduction among current smokers.[36-38] Longitudinal surveys and a few randomized controlled trials have found that e-cigarette use can contribute to smoking reduction,[9,39,40] and one study analyzing multi-year trend data shows that the increase in e-cigarette use is associated with more quitting attempts and quitting success at the population level.[41] However, researchers have not yet reached a consensus about e-cigarettes' efficacy in promoting smoking cessation.[42,43] Because evidence from existing randomized controlled trials and cohort studies was rated as of low certainty,[44,45] more studies, especially those with well-defined control groups and better measures of e-cigarette use and cessation outcomes, are needed to strengthen the evidence base and settle the disagreement.[45,46]

Objectives and Hypotheses

Previous research on spillover effects of vaping cues measured vaping- and smoking-related outcomes during a single experimental session,[21-24] which made it difficult to determine the temporal order. To address this limitation, we employed a 2-wave longitudinal randomized controlled ex-

periment to test the cognitive gateway versus the roadblock hypothesis among young adults who were smokers only and those who were vapers only. The primary goal is to examine the impact of visual vaping cues on smoking/vaping harm perceptions that may either facilitate the transition from vaping to smoking (gateway) or inhibit the transition from smoking to vaping (roadblock).

Based on the cognitive gateway hypothesis, we expect that among e-cigarette users who do not currently smoke, exposure to visual vaping cues in video advertisements will reduce perceived harms of vaping immediately post-exposure (T1), and spill over to reduce perceived harms of smoking 2 weeks later (T2). Conversely, based on the cognitive roadblock hypothesis, we expect that among smokers who do not currently vape e-cigarettes, exposure to visual vaping cues in video advertisements will increase perceived harms of smoking at T1, which will then enhance perceived harms of vaping at T2. By employing a longitudinal design, this study formally operationalized spillover effects, either in the form of a cognitive gateway or a roadblock, as average causal mediation effects of vaping/smoking harm perceptions at T1 mediating treatment effects of vaping cues on smoking/vaping harm perceptions at T2.

METHODS

Participants

In November 2016, participants who were at least 18 years old were recruited from enrolled students at a large midwestern university. The current report focuses on participants who were either current smokers or e-cigarette users because they constituted the relevant populations for the cognitive gateway versus roadblock hypotheses. Current smokers must have smoked at least 100 cigarettes in their lifetime and currently smoke cigarettes *every day* or *some days*, and current e-cigarette users must currently vape e-cigarettes *every day* or *some days*. Non-vaping smokers refer to current smokers who did not meet the criteria for current e-cigarette users, and non-smoking e-cigarette users refer to current e-cigarette users who did not meet the criteria for current smokers. Dual users must meet both criteria, and they were separated from the other 2 groups in following analyses. Of 3341 participants who completed the first wave of the study, those who reported being neither current smokers nor current e-cigarette users (N = 2916) were excluded from further analyses. At T2, 251 participants (149 current smokers, 77 current e-cigarette users and 25 dual users) completed both waves of the study and formed the analytical sample for the current report. The attrition rate was 40.9% from T1 to T2.

Study Design and Data Collection

This study employed a 3-condition (*vaping cue*, *no cue,* and *neutral* video advertisements) longitudinal between-subject design to test the immediate and delayed effects of exposure to visual vaping cues in video commercials on harm perceptions of smoking and vaping. Outcomes were measured both at T1 and T2, with a follow-up period of 2 weeks between waves. Randomization, stimuli display, and data collection at both waves were administered online through the Qualtrics research platform.

At T1, after providing consent, participants first answered questions assessing demographic characteristics. In the informed consent, participants were told that the purpose of the study is to better understand their perceptions of e-cigarettes and the use of e-cigarettes. All participants were blind to specific study hypotheses. Next, all participants were randomly assigned to one of 3 video conditions. In all conditions, they were instructed to "view a series of short videos and answer a few questions about them". All participants were blind to study hypotheses. In each condition, participants were exposed to 5 advertisements randomly selected from a larger pool (11 in the *vaping cue* condition, 12 in the *no cue* condition, and 10 in the *neutral* condition). Each advertisement was displayed individually on a single web page. To ensure that participants viewed each video advertisement, a "continue" button, which allowed participants to proceed to the next video advertisement, would appear after 30 seconds had passed. After viewing all 5 video advertisements, participants were asked to self-report their smoking and vaping harm perceptions and other measures including attitudes, intention to smoke and vape, and perceived effectiveness (not presented here). Upon completion of the T1 study, participants were asked to indicate their willingness to participate in the follow-up survey (T2). Those

agreeing to participate were re-contacted 2 weeks later. At T2, participants were asked to report their smoking and vaping harm perceptions. All participants who completed the T1 study were eligible for a prize drawing to win one of 5 gift cards valued at $50 - $100 each. All participants completing T2 were given a $5 Amazon gift card for their time.

Message Stimuli

All video advertisements were identified through an extensive online search conducted in 2016. Unlike previous research on visual vaping cues,[24] in the current study, advertisements in the *vaping cue* condition must have explicitly depicted the action of vaping via hand-to-mouth gesture and oral consumption. These advertisements also may include peripheral cues such as objects associated with vaping (eg, the liquid delivery device itself) and indirect behaviors (eg, merely holding an e-cigarette). However, commercials merely containing peripheral vaping cues, but no depiction of the vaping action, were excluded from the *vaping cue* condition. After screening for production quality and explicit vaping cues, we identified 11 commercials that were deemed to be acceptable. These advertisements covered many brands (eg, VaporZone, Fin, Blu Cigs, NJOY King), featured a variety of scenes, and used many aesthetic styles. Consistent with a previous content analysis of e-cigarette videos,[47] major themes included: (1) e-cigarettes pose few health risks; (2) e-cigarettes should be adopted as a safer and healthier alternative to smoking; and (3) e-cigarettes can be used in places where smoking is banned. Featured products included cigarette-likes and mid-sized vape pens that resemble combustible cigarettes in shape.

To control for the presence of vaping cues, 12 e-cigarette advertisements (eg, Vape, Pink Spot, Volcano, Chase) *without* depictions of the vaping action were identified for the *no cue* condition. Most commercials contained peripheral vaping cues. These advertisements used similar scenes, types of e-cigarette products (10 featured cig-likes/vape pens and 2 featured MOD devices), the presence of human characters, styles, and themes as those in the *vaping cue* condition. To control further for the hand-to-mouth motion and kinetic properties associated with oral suction, 10 advertisements depicting drinking a beverage (eg, bottled water, coke, orange juice) were identified for the *neutral* condition. This double-control design strengthens the credibility to attribute effects on harm perceptions to visual vaping cues in a causal manner. Furthermore, in each condition, randomly selecting 5 videos from a larger pool created an almost unique message combination and viewing experience for each participant. Therefore, the concern that between-condition differences might be attributed to idiosyncratic features of a single advertisement was eliminated by design. Each ad in the 3 conditions was edited to be approximately 30 seconds to ensure that participants were exposed to equal viewing times in the experiment.

Measures

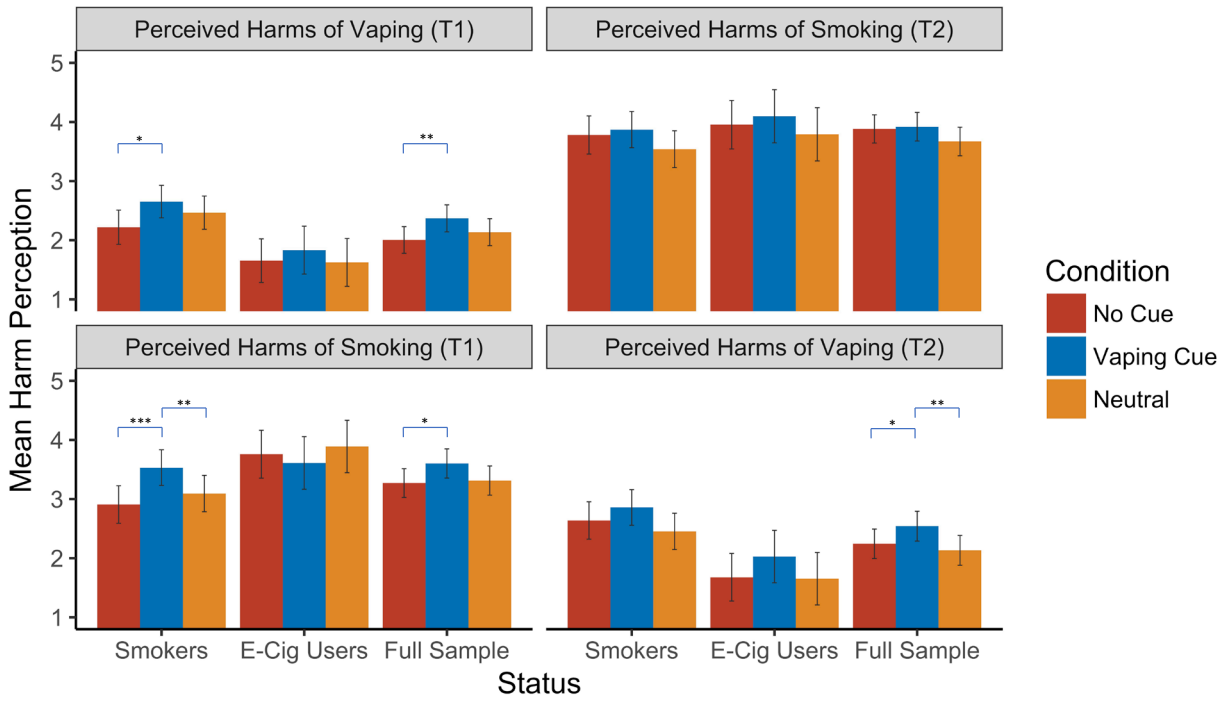
Smoking and vaping harm perceptions were the primary outcomes. These were assessed by asking participants: "How likely do you think it is that smoking/vaping (using e-cigarettes) regularly would cause you to develop each of the following diseases in the next 10 years?" Participants were asked to indicate their perceived risk on a 5-point scale from 1 *(Not at all likely)* to 5 *(Extremely likely*) respectively for *lung cancer*, *heart disease*, and *mouth or throat cancer*. The same measures were employed at T1 and T2. The 3 items were averaged to form a single score respectively for *perceived harms of smoking* (T1: Cronbach's α = 96, M = 3.39, SD = 1.15; T2: Cronbach's α = .96, M = 3.83, SD = 1.12), and *perceived harms of vaping* (T1: Cronbach's α = .96, M = 2.17, SD = 1.06; T2: Cronbach's α = .96, M = 2.31, SD = 1.18).

Other baseline characteristics were assessed, including age, race, sex, sexual orientation, class rank, campus and college affiliation, GPA, urge to smoke and vape, and smoking/e-cigarette use status. We did not measure baseline harm perceptions or exposure to e-cigarette advertising or visual vaping/smoking cues to avoid priming participants to these variables prior to viewing the experimental stimuli.

Data Analysis

To assess whether attrition from T1 to T2 may have impacted randomization, experimental conditions were used to predict the probability of dropping out in a logistic regression model. Drop-out probability did not differ significantly between ex-

Figure 1
Group Means by Condition, Smoking/Vaping Status and Outcome



***p < .1, **p < .05, ***p < .01**

Note.
Error bars depict 95% CIs for group means. The top 2 panels address the cognitive gateway hypothesis whereas the bottom 2 panels address the cognitive roadblock hypothesis.

perimental conditions (likelihood ratio test, $\chi^2(2) = .06$, p = .971). Furthermore, pre-treatment covariates and T1 smoking/vaping harm perceptions also were added to predict the probability of dropping out. Again, baseline characteristics, T1 harm perceptions, condition assignment, and interaction terms between conditions and smoking/vaping statuses as a block did not significantly predict the probability of dropping out (likelihood ratio test, χ^2 (30) = 43.40, p = .265). These results considerably mitigated the concern that attrition may have impacted the random assignment.

Linear regression models were fitted to predict *perceived harms of smoking/vaping* with condition-indicators (the reference category is the *vaping cue* condition). These models estimated main effects of message conditions for the full sample. Next, we estimated the treatment effects for subgroups by adding main effects of smoking/vaping status and interaction terms between condition and smoking/vaping status. Huber–White robust standard errors were applied to models for *perceived harms of vaping* due to detected heteroscedasticity based on significant Breusch-Pagan tests. Analyses were conducted using the statistical language *R* (version 3.3.1).

Average causal mediation effects (*ACME*) of *perceived harms of smoking/vaping* at T1 mediating treatment effects on *perceived harms of vaping/smoking* at T2 were non-parametrically estimated using the methods developed by Imai et al,[48] and the *R* package *mediation*[49] (version 4.4.5). Because the urge to smoke/vape may affect harm perceptions,[50] pre-treatment *urge to smoke* and *urge to vape* also were included to improve the credibility of the sequential ignorability assumptions[48] for both the mediator and the outcome models. Other pre-treatment covariates (ie, *age, college, GPA, sex*) also were

Table 1
Baseline Sample Characteristics, Stratified by Message Condition

	Total Sample (N = 251)	Message Condition			p-value
		Vaping Cue (N = 83)	No Cue (N = 85)	Neutral (N = 83)	
Continuous: Mean (SD)					
Age	26.52 (9.3)	27.27 (9.92)	26.7 (9.27)	25.58 (8.73)	p = .51
Urge to smoke (Pre-treatment)	2.78 (1.78)	2.97 (1.76)	2.57 (1.75)	2.8 (1.82)	p = .35
Urge to vape (Pre-treatment)	2.39 (1.62)	2.34 (1.47)	2.38 (1.64)	2.44 (1.75)	p = .93
Smoking/E-cigarette Use Status					p = .88
Non-vaping smokers	149	52 (34.9%)	47 (31.5%)	50 (33.6%)	
Non-smoking e-cigarette users	77	24 (31.2%)	29 (37.7%)	24 (31.2%)	
Dual users	25	7 (28.0%)	9 (36.0%)	9 (36.0%)	
Class Rank					p = .20
Freshman	44	20 (45.5%)	13 (29.5%)	11 (25.0%)	
Sophomore	52	13 (25.0%)	16 (30.8%)	23 (44.2%)	
Junior	49	19 (38.8%)	14 (28.6%)	16 (32.7%)	
Senior	71	21 (29.6%)	31 (43.7%)	19 (26.8%)	
Graduate	35	10 (28.6%)	11 (31.4%)	14 (40.0%)	
Campus					p = .53
Main campus	159	49 (30.8%)	54 (34.0%)	56 (35.2%)	
Other campus	92	34 (37.0%)	31 (33.7%)	27 (29.3%)	
College					p = .46
Business	30	8 (26.7%)	13 (43.3%)	9 (30.0%)	
Communication	32	7 (21.9%)	9 (28.1%)	16 (50.0%)	
Health	60	19 (31.7%)	22 (36.7%)	19 (31.7%)	
SAS	79	29 (36.7%)	27 (34.2%)	23 (29.1%)	
Other	50	20 (40.0%)	14 (28.0%)	16 (32.0%)	
GPA					p = .30
A-/A	103	35 (34.0%)	39 (37.9%)	29 (28.2%)	
B-/B/B+	113	33 (29.2%)	37 (32.7%)	43 (38.1%)	
C/D	12	4 (33.3%)	2 (16.7%)	6 (50.0%)	
Unknown	23	11 (47.8%)	7 (30.4%)	5 (21.7%)	
Race					p = .60
White	217	70 (32.3%)	76 (35.0%)	71 (32.7%)	
Non-white	34	13 (38.2%)	9 (26.5%)	12 (35.3%)	
Sex					p = .26
Women	152	49 (32.2%)	47 (30.9%)	56 (36.8%)	
Men	99	34 (34.3%)	38 (38.4%)	27 (27.3%)	
Sexual Orientation					p = .11
Heterosexual	203	71 (35.0%)	71 (35.0%)	61 (30.0%)	
LGBT	48	12 (25.0%)	14 (29.2%)	22 (45.8%)	

Note.
All variables were compared between groups with F-test and chi-square test as appropriate.

Table 2
Main and Average Causal Mediation Effects Testing the Cognitive Gateway Hypothesis

	Comparison	Full Sample	Non-vaping Smokers	Non-smoking E-cigarette Users
Main Effects of Visual Vaping Cues[a] (unstandardized coefficient [95% CI])				
Perceived harms of vaping (T1)	Vaping cue vs No cue	**.37**** **[.04, .70]**	.43* [-.01, .88]	.18 [-.28, .64]
			Interaction: $b_{\text{e-cigarette users}} - b_{\text{smokers}} = -.26$ 95% CI [-.89, .38]	
	Vaping cue vs Neutral	.23 [-.11, .58]	.19 [-.27, .64]	.21 [-.24, .66]
			Interaction: $b_{\text{e-cigarette users}} - b_{\text{smokers}} = .02$ 95% CI [-.62, .66]	
Perceived harms of smoking (T2)	Vaping cue vs No cue	.04 [-.30, .38]	.09 [-.35, .53]	.14 [-46, .75]
			Interaction: $b_{\text{e-cigarette users}} - b_{\text{smokers}} = .05$ 95% CI [-.70, .80]	
	Vaping cue vs Neutral	.25 [-.09, .59]	.33 [-.10, .77]	.31 [-.33, .94]
			Interaction: $b_{\text{e-cigarette users}} - b_{\text{smokers}} = .03$ 95% CI [-.80, .74]	
Average Causal Mediation Effects of Perceived Harms of Vaping at T1[b] (ACME [95% CI])				
Treatment → Perceived harms of vaping (T1) → Perceived harms of smoking (T2)	Vaping cue vs No cue	.06 [-.02, .17]	.12 [-.05, .34]	-.03 [-.22, .11]
			$ACME_{\text{e-cigarette users}} - ACME_{\text{smokers}} = -.14$ 95% CI [-.42, .08]	
	Vaping cue vs Neutral	.06 [-.03, .16]	.06 [-.12, .26]	-.04 [-.26, .10]
			$ACME_{\text{e-cigarette users}} - ACME_{\text{smokers}} = -.11$ 95% CI [-.39, .11]	

***p < .10; **p < .05**

Note.
a: Unstandardized coefficients and 95% CIs of estimated between-condition differences based on OLS regressions. For each column except Full Sample, the reference group was set to the corresponding column name to obtain estimates for the referenced sub-group while preserving all observations in the full sample.
b: ACME = average causal mediation effect, CI = confidence intervals based on quasi-Bayesian Monto Carlo approximation with robust standard errors (1000 simulations).[45,46]

included in both models because they were found to be significant predictors of harm perceptions at either wave, and thus, potentially confounding the mediator-outcome paths. The moderated mediation analysis estimated the difference in each *ACME* of T1 harm perceptions between smokers and e-cigarette users. We constructed 95% CIs for *ACMEs* and moderated mediation effects using the quasi-Bayesian Monte Carlo approximation (1000 simulations).[48,49] Due to the small number of dual users (N = 25), results were not reported for this sub-group but can be found in the Supplementary Materials (Supplementary Tables 1-2).

RESULTS

Table 1 summarizes the sample characteristics for the full sample and those stratified by message condition. The mean age for the sample was 27 years, 61% were women, and 86% were white. Figure 1

Table 3
Main and Average Causal Mediation Effects Testing the Cognitive Roadblock Hypothesis

	Comparison	Full Sample	Non-vaping Smokers	Non-smoking E-cigarette Users
Main Effects of Visual Vaping Cues [a] (unstandardized coefficient [95% CI])				
Perceived harms of smoking (T1)	Vaping cue vs No cue	0.33* [-0.01, 0.68]	**0.62*** [0.19, 1.06]**	-0.15 [-0.75, 0.45]
			Interaction: $b_{smokers}$ - $b_{e\text{-}cigarette\ users}$ = .77 95% CI [.03, 1.52]**	
	Vaping cue vs Neutral	0.29 [-0.06, 0.64]	**0.44** [0.01, 0.87]**	-0.28 [-0.90, 0.35]
			Interaction: $b_{smokers}$ - $b_{e\text{-}cigarette\ users}$ = .72* 95% CI [-.04, 1.48]	
Perceived harms of vaping (T2)	Vaping cue vs No cue	0.30* [-0.06, 0.65]	0.22 [-0.26, 0.70]	0.35 [-0.15, 0.85]
			Interaction: $b_{smokers}$ - $b_{e\text{-}cigarette\ users}$ = -.13 95% CI [-.82, .56]	
	Vaping cue vs Neutral	**0.41** [0.05, 0.77]**	0.41 [-0.10, 0.91]	0.38 [-0.17, 0.92]
			Interaction: $b_{smokers}$ - $b_{e\text{-}cigarette\ users}$ = .03 95% CI [-.71, .77]	
Average Causal Mediation Effects of Perceived Harms of Smoking at T1 [b] (ACME [95% CI])				
Treatment → Perceived harms of smoking (T1) → Perceived harms of vaping (T2)	Vaping cue vs No cue	.06 [-.02, .17]	**.23** [.02, .48]**	.01 [-.07, .11]
			$ACME_{smokers}$ - $ACME_{e\text{-}cigarette\ users}$ = .22 95% CI [.00, .47]**	
	Vaping cue vs. Neutral	.08* [-.01, .19]	**.20** [.00, .46]**	.01 [-.07, .13]
			$ACME_{smokers}$ - $ACME_{e\text{-}cigarette\ users}$ = .17 95% CI [-.05, .43]	

***p < .10; **p < .05; ***p < .01**

Note
a: Unstandardized coefficients and 95% CIs of estimated between-condition differences based on OLS regressions. For each column except Full Sample, the reference group was set to the corresponding column name to obtain estimates for the referenced sub-group while preserving all observations in the full sample.
b: ACME = average causal mediation effect, CI = confidence intervals based on quasi-Bayesian Monto Carlo approximation with robust standard errors (1000 simulations).[45,46]

presents the point estimates and 95% confidence intervals of group means stratified by message condition, smoking/vaping status, outcome, and time. Table 2 and Table 3 summarize main effects of visual vaping cues, interaction effects with smoking/vaping status, average causal mediation effects of T1 harm perceptions, and moderated mediation effects by smoking/vaping status. Results were organized to address the cognitive gateway (Table 2) and roadblock (Table 3) hypotheses, respectively.

The cognitive gateway hypothesis predicts that at T1, exposure to visual vaping cues would *reduce* perceived harms of vaping among non-smoking e-cigarette users. In the *vaping cue* versus *no cue* comparison and the *vaping cue* versus *neutral* comparison, no significant effects of vaping cues were found for non-smoking e-cigarette users (Table 2).

The cognitive gateway hypothesis also predicts that effects of vaping cues on perceived harms of vaping at T1 would spill over to reduce perceived

harms of smoking at T2. Contrary to this hypothesis, at T2, non-smoking e-cigarette users in the *vaping cue* condition did not significantly differ in perceived harms of smoking from those in the *no cue* or the *neutral* condition. The average causal mediation effects of T1 perceived harms of vaping were not statistically significant in either comparison among non-smoking e-cigarette users (Table 2). Therefore, the data did not provide convincing evidence to support the cognitive gateway hypothesis.

The cognitive roadblock hypothesis predicts that at T1, exposure to visual vaping cues would *increase* perceived harms of smoking among non-vaping smokers. In support of this hypothesis, non-vaping smokers viewing video advertisements with vaping cues perceived smoking to be more harmful than those viewing *no cue* (b = .62, 95% CI [.19, 1.06], p = .005) or *neutral* advertisements (b = .44, 95% CI [.01, .87], p = .046) (Table 3). Also, interaction tests suggest that the effects of visual vaping cues were significantly stronger for non-vaping smokers than non-smoking e-cigarette users in the critical comparison with the *no cue* condition (b = .77, 95% CI [.03, 1.52], p = .042).

The cognitive roadblock hypothesis further predicts that increased perceived harms of smoking at T1 would mediate the effects of vaping cues to *heighten* perceived harms of vaping at T2. Non-vaping smokers in the *vaping cue* condition did not significantly differ in perceived harms of vaping at T2 from those in either the *no cue* or the *neutral* condition (Table 3). However, for non-vaping smokers, the delayed effects of visual vaping cues on perceived harms of vaping at T2 were significantly mediated by perceived harms of smoking at T1 (versus *no cue*: *ACME* = .23, 95% CI [.02, .48], p = .020; versus *neutral*: *ACME* = .20, 95% CI [.00, .46], p = .048); and this mediation path was larger than that of non-smoking e-cigarette users in the critical comparison with the *no cue* condition (*ACMEsmokers- ACMEe-cigarette users* = .22, 95% CI [.00, .47], p = .048)(Table 3). In short, our data supported the cognitive roadblock hypothesis.

Among *dual users*, visual vaping cues increased perceived harms of smoking at T1 (versus *neutral*: b = 1.10, 95% CI [.00, 2.19], p = .050) but did not show other effects. Therefore, neither the cognitive gateway nor the roadblock hypothesis was consistently supported by data among this subgroup (see Tables S1-S2 for details).

DISCUSSION

Results from this randomized experiment demonstrated that brief exposure to visual portrayals of vaping in e-cigarette video commercials could have both immediate and delayed effects on harm perceptions among young adult non-vaping smokers, albeit in a direction to potentially thwart rather than promote e-cigarette use. To the best of our knowledge, our study provides the first set of experimental evidence supporting the causal impact of exposure to visual vaping cues on harm perceptions that could potentially impact the transition from vaping to smoking (gateway) versus smoking to vaping (roadblock), respectively.

With the rapid increase in advertising expenditure from the e-cigarette industry,[18,19] exposure to video advertisements among young adults has been proliferating,[20] subjecting this already susceptible group to influences from both potentially misleading verbal claims and visual vaping cues. Verbal modified risk claims that attempt to portray e-cigarette as "harmless," "a healthier alternative," or "an indispensable tool in the pathway to quitting"[51-53] are now subject to review under the FDA's deeming rule;[15] however, visual vaping cues remain peripheral to the attention of regulatory authorities. Building upon previous research that has established the role of visual vaping cues in temporarily inducing the urge to smoke/vape,[21-24] we demonstrated that such visual cues also could affect judgments about the likelihood of contracting cancer and other diseases as a result of e-cigarette vaping. Exposure to visual vaping cues was found to heighten harm perceptions, which may potentially reduce, rather than increase, vaping among current non-vaping smokers. These findings underscore the need to monitor visual elements, especially vaping portrayals, in e-cigarette advertisements. The pattern of findings from this study, however, differ for non-smoking e-cigarette users and non-vaping smokers. Therefore, implications for public health are discussed respectively for these 2 subgroups.

First, for young adult vapers who were not current smokers, health experts are concerned that experimenting with e-cigarettes may induce nicotine dependence, a gateway to cigarette smoking and

abuse of illicit drugs.[8,26,27] Although some longitudinal surveys have found that baseline e-cigarette use was associated with smoking initiation later,[54,55] critics stressed the lack of sufficient data to support this "gateway hypothesis."[27,38] The e-cigarette-as-gateway hypothesis consists of multiple steps: the first step concerns the initiation of e-cigarette use among never users of any nicotine products, and the second concerns the transition from vaping e-cigarettes to smoking combustible cigarettes, and perhaps, using other illicit drugs. Our results address one cognitive component of the second step (transition) by showing that among non-smoking e-cigarettes users, brief exposure to visual vaping cues did not significantly reduce perceived harms of smoking—a known psychological precursor to actual smoking behaviors[34] – either immediately or 2 weeks later. In fact, after exposure to e-cigarette advertisements containing vaping cues, non-smoking e-cigarette users reported higher, although not statistically significant, vaping harm perceptions at T1 and smoking harm perceptions at T2, contrary to the cognitive gateway hypothesis. Given the small sample size for e-cigarette users (N = 77), future research should seek to gauge the robustness of these findings with a larger sample.

It is important to acknowledge that e-cigarette advertising might activate the gateway effect through mechanisms other than the cognitive route tested in this study. For example, exposure to promotional advertisements could reinforce habitual use among non-smoking e-cigarette users, which may intensify nicotine dependence and accelerate transition to combustible cigarettes. Nicotine dependence represents a neural and physiological pathway[26] beyond harm perceptions.

Second, for young non-vaping smokers, exposure to visual vaping cues, compared to no cue or to bottled drink videos, resulted in higher perceived harms of smoking at T1, which in turn, translated into higher perceived harms of vaping 2 weeks later. Immediately following advertisement exposure, perceived harms of smoking were measured and were found to mediate the effects of exposure to visual vaping cues. Mediation effects of *smoking*-related harm perceptions strengthened the interpretation that vaping cues' somewhat counter-intuitive effects to *increase* perceived harms of vaping were partially attributable to visual similarity between vaping and smoking cues. Just as visual vaping cues could increase the urge to smoke,[21-24] they also were found to activate existing beliefs about health risks associated with smoking; moreover, harm perceptions about smoking further increased perceived harms of vaping 2 weeks later. Similar findings also were replicated with data on mediators and outcomes both measured at T1 (for details, see Table S3 in the Supplementary Materials). The cognitive roadblock effect of visual vaping cues, as this study shows, offers one plausible explanation for a documented increase in perceived harms of vaping among current smokers in recent years,[3,4,14] as the cognitive roadblock effect suggests that negative cognitions about smoking could be activated by visual vaping cues and generalized to vaping. However, it is important to note other plausible contributing factors such as sensational media coverage of adverse impacts of e-cigarette use.[4] Because the cognitive roadblock effect was observed in the setting of a controlled experiment, future research should monitor such effects in non-vaping smokers' everyday life. On the one hand, routine exposure to e-cigarette advertising[20,56] could intensify the cognitive roadblock effect and result in an even more sizable increase in perceived harms of vaping; on the other hand, routine exposure may render the distinction between e-cigarettes and combustible cigarettes more salient, reducing cross-product generalizations and dissipating the cognitive roadblock effect. Longitudinal evidence is needed to draw conclusions about these diverging projections. Whether findings from this study are a concern for public health also depends upon continuing research to clarify to what degree the cognitive roadblock effect would yield behavioral impact inhibiting non-vaping smokers from switching to e-cigarettes. Switching to e-cigarettes could result in temporary harm reduction for smokers,[36,37] which should nevertheless be weighed against long-term costs such as delayed abstinence from nicotine.[57,58]

Among *dual users*, the data did not consistently support either the cognitive gateway or the roadblock hypothesis, although exposure to visual vaping cues marginally increased perceived harms of smoking at T1 (versus the *neutral* condition). Given the small sample size for this subgroup (N = 25), our study was under-powered to estimate true effects. Future research should examine cognitive gateway/roadblock effects with a larger sample of dual users.

A previous randomized controlled experiment showed that exposure to e-cigarette advertisement resulted in reduced, not heightened, perceived harms of vaping.[25] This discrepancy is likely to be caused by sample difference, as the sample in the study conducted by Farrelly et al[25] consisted of never e-cigarette users and predominantly never smokers (94.5%). Also, in that study, no differentiation was made between e-cigarette advertisements with visual vaping cues versus those without visual vaping cues.

Lastly, it should be emphasized that the cognitive gateway/roadblock effect examined in this study does not equate the actual behavior of smoking/vaping. Future research should seek to further examine whether visual vaping cues' effects on harm perceptions would translate into smokers' actual vaping behaviors.

Limitations

The attrition rate from T1 to T2 was higher than ideal. With that said, attrition did not significantly differ by experimental condition, nor was the probability of dropping out between T1 and T2 predictable from a battery of pre-treatment covariates, condition assignments, as well as their interaction terms with smoking/vaping status at T1, and harm perceptions at T1. These results increased our confidence that attrition did not systematically impact randomization nor bias the interpretation of main effects of visual vaping cues. Furthermore, the sample for this study was relatively small and limited to students at one university who either currently smoke or vape. Future research should replicate these results with a more representative sample of adult smokers and e-cigarette users, and also extend the focus to examine how never users of either tobacco product react to visual vaping cues in e-cigarette advertising.

IMPLICATIONS FOR TOBACCO REGULATION

Our findings are relevant as regulatory authorities consider regulating e-cigarette advertising. Unlike verbal claims such as modified risk claims, currently there are no regulations specific to visual components in e-cigarette advertising. Based on our data, the concern that visual portrayals of vaping could lower harm perceptions may not be warranted; exposure to such visual vaping cues did not reduce harm perceptions about either vaping or smoking among young adult vapers, thereby mitigating the concern that e-cigarette use would transition into smoking through the cognitive route. If anything, the pattern of findings is consistent with roadblock effects manifested as increased harm perceptions among young adult smokers, which warrants future research to evaluate whether such cognitive effects would inhibit smokers from switching to e-cigarettes, a potential harm reduction alternative.

Human Subjects Statement

The Kent State University Institutional Review Board approved the study.

Conflict of Interest Statement

All authors of this article declare they have no conflicts of interest.

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References

1. Dinakar C, O'Connor GT. The health effects of electronic cigarettes. *N Engl J Med*. 2016;375(14):1372-1381.
2. Glasser AM, Collins L, Pearson JL, et al. Overview of electronic nicotine delivery systems: a systematic review. *Am J Prev Med*. 2017;52(2):e33-e66.
3. Huerta TR, Walker DM, Mullen D, et al. Trends in e-cigarette awareness and perceived harmfulness in the U.S. *Am J Prev Med*. 2017;52(3):339-346.
4. Majeed BA, Weaver SR, Gregory KR, et al. Changing perceptions of harm of e-cigarettes among U.S. adults, 2012–2015. *Am J Prev Med*. 2017;52(3):331-338.
5. Goniewicz ML, Knysak J, Gawron M, et al. Levels of selected carcinogens and toxicants in vapour from electronic cigarettes. *Tob Control*. 2014;23(2):133-139.
6. Hecht SS, Carmella SG, Kotandeniya D, et al. Evaluation of toxicant and carcinogen metabolites in the urine of e-cigarette users versus cigarette smokers. *Nicotine Tob Res*.

2015;17(6):704-709.
7. Hajek P, Etter J-F, Benowitz N, et al. Electronic cigarettes: review of use, content, safety, effects on smokers and potential for harm and benefit. *Addict*. 2014;109(11):1801-1810.
8. Glynn TJ. E-cigarettes and the future of tobacco control. *CA Cancer J Clin*. 2014;64(3):164-168.
9. Adkison SE, O'Connor RJ, Bansal-Travers M, et al. Electronic nicotine delivery systems: international tobacco control four-country survey. *Am J Prev Med*. 2013;44(3):207-215.
10. Choi K, Forster JL. Beliefs and experimentation with electronic cigarettes: a prospective analysis among young adults. *Am J Prev Med*. 2014;46(2):175-178.
11. Waters EA, Mueller-Luckey G, Levault K, Jenkins WD. Perceived harms and social norms in the use of electronic cigarettes and smokeless tobacco. *J Health Commun*. 2017;22(6):497-505.
12. Wackowski OA, Delnevo CD. Young adults' risk perceptions of various tobacco products relative to cigarettes: results from the National Young Adult Health Survey. *Health Educ Behav*. 2016;43(3):328-336.
13. Amrock SM, Zakhar J, Zhou S, Weitzman M. Perception of e-cigarette harm and its correlation with use among U.S. adolescents. *Nicotine Tob Res*. 2015;17(3):330-336.
14. Brose LS, Brown J, Hitchman SC, McNeill A. Perceived relative harm of electronic cigarettes over time and impact on subsequent use: a survey with 1-year and 2-year follow-ups. *Drug Alcohol Depend*. 2015;157:106-111.
15. US Food and Drug Administration. Deeming tobacco products to be subject to the Federal Food, Drug, and Cosmetic Act, as amended by the Family Smoking Prevention and Tobacco Control Act; restrictions on the sale and distribution of tobacco products and required warning statements for tobacco products. Final rule. *Fed Regist*. 2016;81(90):28973-29106.
16. Padon AA, Maloney EK, Cappella JN. Youth-targeted e-cigarette marketing in the US. *Tob Regul Sci*. 2017;3(1):95-101.
17. Richardson A, Ganz O, Stalgaitis C, et al. Noncombustible tobacco product advertising: how companies are selling the new face of tobacco. *Nicotine Tob Res*. 2014;16(5):606-614.
18. Kim AE, Arnold KY, Makarenko O. E-cigarette advertising expenditures in the U.S., 2011-2012. *Am J Prev Med*. 2014;46(4):409-412.
19. Cantrell J, Emelle B, Ganz O, et al. Rapid increase in e-cigarette advertising spending as Altria's MarkTen enters the marketplace. *Tob Control*. 2015;25:e16-e18.
20. Duke JC, Lee YO, Kim AE, et al. Exposure to electronic cigarette television advertisements among youth and young adults. *Pediatrics*. 2014;134(1):e29-e36.
21. King AC, Smith LJ, Fridberg DJ, et al. Exposure to electronic nicotine delivery systems (ENDS) visual imagery increases smoking urge and desire. *Psychol Addict Behav*. 2016;30(1):106-112.
22. King AC, Smith LJ, McNamara PJ, Cao D. Second generation electronic nicotine delivery system vape pen exposure generalizes as a smoking cue. *Nicotine Tob Res*. 2018;20(2):246-252.
23. King AC, Smith LJ, McNamara PJ, et al. Passive exposure to electronic cigarette (e-cigarette) use increases desire for combustible and e-cigarettes in young adult smokers. *Tob Control*. 2014;24(5):501-504.
24. Maloney EK, Cappella JN. Does vaping in e-cigarette advertisements affect tobacco smoking urge, intentions, and perceptions in daily, intermittent, and former smokers? *Health Commun*. 2016;31(1):129-138.
25. Farrelly MC, Duke JC, Crankshaw EC, et al. A randomized trial of the effect of e-cigarette TV advertisements on intentions to use e-cigarettes. *Am J Prev Med*. 2015;49(5):686-693.
26. Kandel ER, Kandel DB. A molecular basis for nicotine as a gateway drug. *N Engl J Med*. 2014;371(10):932-943.
27. Bell K, Keane H. All gates lead to smoking: the "gateway theory," e-cigarettes and the remaking of nicotine. *Soc Sci Med*. 2014;119:45-52.
28. Coleman BN, Apelberg BJ, Ambrose BK, et al. Association between electronic cigarette use and openness to cigarette smoking among US young adults. *Nicotine Tob Res*. 2015;17(2):212-218.
29. Bunnell RE, Agaku IT, Arrazola RA, et al. Intentions to smoke cigarettes among never-smoking US middle and high school electronic cigarette users: National Youth Tobacco Survey, 2011–2013. *Nicotine Tob Res*. 2015;17(2):228-235.
30. Dutra LM, Glantz SA. Electronic cigarettes and conventional cigarette use among US adolescents: a cross-sectional study. *JAMA Pediatr*. 2014;168(7):610-617.
31. Soneji S, Barrington-Trimis JL, Wills TA, et al. Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: a systematic review and meta-analysis. *JAMA Pediatr*. 2017;171(8):788-797.
32. Selya AS, Rose JS, Dierker L, et al. Evaluating the mutual pathways among electronic cigarette use, conventional smoking and nicotine dependence. *Addict*. 2017;119:45.
33. Berg CJ, Haardoerfer R, Escoffery C, et al. Cigarette users' interest in using or switching to electronic nicotine delivery systems for smokeless tobacco for harm reduction, cessation, or novelty: a cross-sectional survey of US adults. *Nicotine Tob Res*. 2015;17(2):245-255.
34. Song AV, Morrell HER, Cornell JL, et al. Perceptions of smoking-related risks and benefits as predictors of adolescent smoking initiation. *Am J Public Health*. 2009;99(3):487-492.
35. Abrams DB, Glasser AM, Pearson JL, et al. E-cigarettes as a harm reduction approach. *Annu Rev Public Health*. 2018;38.
36. Nitzkin JL. The case in favor of e-cigarettes for tobacco harm reduction. *Int J Environ Res Public Health*. 2014;11(6):6459-6471.
37. Zeller M. Reflections on the "endgame" for tobacco control. *Tob Control*. 2013;22(Suppl 1):i40-i41.
38. Polosa R, Caponnetto P. Time for evidence-based e-cigarette regulation. *Lancet Oncol*. 2013;14(13):e582-e583.
39. Biener L, Hargraves JL. A longitudinal study of electronic cigarette use among a population-based sample of adult smokers: association with smoking cessation and motivation to Quit. *Nicotine Tob Res*. 2015;17(2):127-133.
40. Tseng T-Y, Ostroff JS, Campo A, et al. A randomized trial comparing the effect of nicotine versus placebo electronic cigarettes on smoking reduction among young adult smokers. *Nicotine Tob Res*. 2016;18(10):1937-1943.

41. Zhu S-H, Zhuang Y-L, Wong S, et al. E-cigarette use and associated changes in population smoking cessation: evidence from US current population surveys. *BMJ*. 2017;358:j3262.
42. Glantz SA, Bareham DW. E-cigarettes: Use, effects on smoking, risks, and policy implications. *Annu Rev Public Health*. 2018;38.
43. Kalkhoran S, Glantz SA. E-cigarettes and smoking cessation in real-world and clinical settings: a systematic review and meta-analysis. *Lancet Respir Med*. 2016;4(2):116-128.
44. Dib RE, Suzumura EA, Akl EA, et al. Electronic nicotine delivery systems and/or electronic non-nicotine delivery systems for tobacco smoking cessation or reduction: a systematic review and meta-analysis. *BMJ*. 2017;7(2):e012680.
45. Villanti AC, Feirman SP, Niaura RS, et al. How do we determine the impact of e-cigarettes on cigarette smoking cessation or reduction? Review and recommendations for answering the research question with scientific rigor. *Addiction*. 2017 Oct 3. doi: 10.1111/add.14020. [Epub ahead of print]
46. Glasser AM, Collins L, Pearson JL, et al. Overview of electronic nicotine delivery systems: a systematic review. *Am J Prev Med*. 2017;52(2):e33-e66.
47. Paek H-J, Kim S, Hove T, Huh JY. Reduced harm or another gateway to smoking? Source, message, and information characteristics of e-cigarette videos on YouTube. *J Health Commun*. 2014;19(5):545-560.
48. Imai K, Keele L, Yamamoto T. Identification, inference and sensitivity analysis for causal mediation effects. *Stat Sci*. 2010;25(1):51-71.
49. Tingley D, Yamamoto T, Hirose K, et al. mediation: R package for causal mediation analysis. *J Stat Softw*. 2014;59(5):38.
50. Sayette MA, Martin CS, Wertz JM, et al. A multi-dimensional analysis of cue-elicited craving in heavy smokers and tobacco chippers. *Addiction*. 2001;96(10):1419-1432.
51. Andrade M de, Hastings G, Angus K. Promotion of electronic cigarettes: tobacco marketing reinvented? *BMJ*. 2013;347:f7473.
52. Zhu S-H, Sun JY, Bonnevie E, et al. Four hundred and sixty brands of e-cigarettes and counting: implications for product regulation. *Tob Control*. 2014;23(Suppl 3):iii3-iii9.
53. Grana RA, Ling PM. "Smoking revolution": a content analysis of electronic cigarette retail websites. *Am J Prev Med*. 2014;46(4):395-403.
54. Primack BA, Soneji S, Stoolmiller M, et al. Progression to traditional cigarette smoking after electronic cigarette use among US adolescents and young Adults. *JAMA Pediatr*. 2015;169(11):1018-1023.
55. Barrington-Trimis JL, Urman R, Berhane K, et al. E-cigarettes and future cigarette use. *Pediatrics*. 2016;138(1):e20160379-e20160379.
56. Pepper JK, Emery SL, Ribisl KM, Brewer NT. How U.S. adults find out about electronic cigarettes: implications for public health messages. *Nicotine Tob Res*. 2014;16(8):1140-1144.
57. Grana RA, Popova L, Ling PM. A longitudinal analysis of electronic cigarette use and smoking cessation. *JAMA Intern Med*. 2014;174(5):812-813.
58. Malas M, van der Tempel J, Schwartz R, et al. Electronic cigarettes for smoking cessation: a systematic review. *Nicotine Tob Res*. 2016;18(10):1926-1936.

Supplementary Table 1
Testing the Cognitive Gateway Hypothesis among Dual Users

	Comparison	Dual Users	
Perceived harms of vaping (T1)	Vaping cue vs No cue	.10 [-1.21, 1.40]	
			Interaction: $b_{dual\ users} - b_{e\text{-}cig\ users}$ = -.08 95% CI [-1.47, 1.30]
			Interaction: $b_{dual\ users} - b_{smokers}$ = -.34 95% CI [-1.72, 1.04]
	Vaping cue vs Neutral	.43 [-.88, 1.73]	
			Interaction: $b_{dual\ users} - b_{e\text{-}cig\ users}$ = .22 95% CI [-1.16, 1.60]
			Interaction: $b_{dual\ users} - b_{smokers}$ = .24 95% CI [-1.14, 1.62]
Perceived harms of smoking (T2)	Vaping cue vs No cue	-.52 [-1.63, .59]	
			Interaction: $b_{dual\ users} - b_{e\text{-}cig\ users}$ = -.66 95% CI [-1.92, .60]
			Interaction: $b_{dual\ users} - b_{smokers}$ = -.61 95% CI [-1.80, .58]
	Vaping cue vs Neutral	-.41 [-1.51, .70]	
			Interaction: $b_{dual\ users} - b_{e\text{-}cig\ users}$ = -.71 95% CI [-1.99, .56]
			Interaction: $b_{dual\ users} - b_{smokers}$ = -.74 95% CI [-1.93, .45]

Note.
Unstandardized coefficients and 95% CIs of estimated between-condition differences based on OLS regressions. All observations in the full sample (N = 251) were preserved when fitting OLS models, and the reference group was set to *dual users* to obtain estimates for this sub-group. Due to the small sample size for *dual users* (N = 25), estimates for this sub-group were unstable and may have overestimated the magnitudes of true effect sizes. Therefore, results for this specific sub-group should be interpreted with caution.

Supplementary Table 2
Testing the Cognitive Roadblock Hypothesis Among Dual Users

	Comparison	Dual Users	
Perceived harms of smoking (T1)	Vaping cue vs No cue	.50 [-.59, 1.60]	
			Interaction: $b_{\text{dual users}} - b_{\text{e-cig users}} = .65$ 95% CI [-.60, 1.90] Interaction: $b_{\text{dual users}} - b_{\text{smokers}} = -.12$ 95% CI [-1.30, 1.05]
	Vaping cue vs Neutral	1.10* [.00, 2.19]	
			Interaction: $b_{\text{dual users}} - b_{\text{e-cig users}} = 1.37^{**}$ 95% CI [.12, 2.63] Interaction: $b_{\text{dual users}} - b_{\text{smokers}} = .66$ 95% CI [-.52, 1.83]
Perceived harms of vaping (T2)	Vaping cue vs No cue	-.05 [-1.36, 1.27]	
			Interaction: $b_{\text{dual users}} - b_{\text{e-cig users}} = -.40$ 95% CI [-1.80, 1.00] Interaction: $b_{\text{dual users}} - b_{\text{smokers}} = -.27$ 95% CI [-1.66, 1.13]
	Vaping cue vs Neutral	.32 [-.85, 1.50]	
			Interaction: $b_{\text{dual users}} - b_{\text{e-cig users}} = -.05$ 95% CI [-1.35, 1.24] Interaction: $b_{\text{dual users}} - b_{\text{smokers}} = -.08$ 95% CI [-1.36, 1.20]

***p < .10; **p < .05**

Note.
Unstandardized coefficients and 95% CIs of estimated between-condition differences based on OLS regressions. All observations in the full sample (N = 251) were preserved when fitting OLS models, and the reference group was set to *dual users* to obtain estimates for this sub-group. Due to the small sample size for *dual users* (N = 25), estimates for this sub-group were unstable and may have overestimated the magnitudes of true effect sizes. Therefore, results for this specific sub-group should be interpreted with caution.

Supplementary Table 3
Testing Average Causal Mediation Effects of Harm Perceptions Using T1 Data Exclusively

	Comaprsions	Full Sample	Smokers	E-Cigarette Users
Treatment → Perceived harms of vaping (T1) → Perceived harms of smoking (T1)	Vaping cue vs No cue	.12 [-.04, .27]	.17 [-.06, .42]	-.00 [-.11, .10]
			$ACME_{E\text{-}Cigarette\ user} - ACME_{smoker}$ = -.18 95% CI [-.44, .08]	
	Vaping cue vs Neutral	.10 [-.06, .28]	.12 [-.15, .39]	-.01 [-.10, .14]
			$ACME_{E\text{-}Cigarette\ user} - ACME_{smoker}$ = -.12 95% CI [-.41, .16]	
Treatment → Perceived harms of smoking (T1) → Perceived harms of vaping (T1)	Vaping cue vs No cue	.11 [-.03, .26]	**.26*** [.05, .51]**	-.01 [-.09, .07]
			$ACME_{smoker}$ - $ACME_{E\text{-}cigarette\ user}$ = .27 95% CI [.03, .53]**	
	Vaping cue vs Neutral	.12* [-.02, .28]	**.29*** [.04, .56]**	**-.01 [-.11, .07]**
			$ACME_{smoker}$ - $ACME_{E\text{-}cigarette\ user}$ = .30 95% CI [.05, .56]**	

***p < .10; **p < .05; ***p < .01**

Note.
ACME = average causal mediation effect, CI = confidence intervals based on quasi-Bayesian Monto Carlo approximation with robust standard errors (sims = 1000).