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Countering online marketing and user endorsements with enhanced cannabis warning labels: An online experiment among at-risk youth and young adults

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ABSTRACT

As cannabis legalization expands and online marketing intensifies, this study examines whether online social cues can amplify youth-targeted cannabis advertising and whether cannabis warning labels (CWLs) can counteract these influences. A U.S. online sample of 970 adolescents and 1776 young adults susceptible to cannabis use were recruited from Qualtrics in summer 2022. Each participant was randomly assigned to one of the 3 (CWLs: none vs. textual vs. pictorial) by 3 (comments: none vs. anti-cannabis vs. pro-cannabis) conditions in an online experiment. Participants were exposed to three online marketing posts promoting marijuana edibles (randomly selected from a large pool, $N = 1260$), each with either no warning label, a textual warning, or a pictorial warning (text and picture), and with either five comments (pro- or anti-cannabis in valence) or none. Results showed that among adolescents, pro-cannabis comments increased product appeal (vs. anti-cannabis comments: $b = 0.18$, $p = .025$; vs. no comments: $b = 0.21$, $p = .021$), and did so more than young adults. For adolescents, only pictorial warnings reduced product appeal ($b = -0.20$, $p = .028$). For young adults, both pictorial ($b = -0.18$, $p = .002$) and textual warnings ($b = -0.12$, $p = .029$) reduced product appeal. Furthermore, both textual (adolescents: $b = -0.20$, $p = .004$; young adults: $b = -0.15$, $p = .005$) and pictorial (adolescents: $b = -0.30$, $p < .001$; young adults: $b = -0.18$, $p = .001$) warnings reduced cannabis use intentions. Findings support requiring enhanced CWLs accompany online marketing ads.

1. Introduction

As of early 2023, 22 U.S. states and Washington DC, have legalized non-medical cannabis and all but three states have legalized cannabis to some degree (National Conference of State Legislators, 2022; Hansen et al., 2023). In 2021, 43% of young adults reported past-year use, and 11% reported daily use, the highest since 1988 (NIDA, 2022). For adolescents at 8th, 10th, and 12th grades, the rates of daily cannabis use in 2020 reached or were near the highest levels since 1991, although there was a decline in daily use between 2020 and 2021 (Johnston et al., 2021). Early onset of regular cannabis use is associated with higher risks for psychotic symptoms, cardiovascular disease, cognitive impairments, and poorer educational and vocational attainment (Groce, 2018; Shahzade et al., 2018; Silins et al., 2014; Volkow et al., 2016). Furthermore, the growing cannabis industry has increased THC concentrations in products (Freeman et al., 2021). In the U.S., the THC concentration for most advertised cannabis products in online dispensaries is over 15%, considered high potency (Cash et al., 2020). National survey data also show that participants living in states that have legalized recreational cannabis use are more likely to use high-potency THC concentrates (Hasin et al., 2015). High potency strains and products are associated with a higher risk of adverse health consequences, including addiction, psychosis, anxiety disorders, and cannabis use disorders (Petrilli et al., 2022; Gorelick, 2023; Hines et al., 2020; Wilson et al., 2019).

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Of particular concern is the rise of edible use among youth in states that have legalized recreational cannabis products (Borodovsky et al., 2017). In this age group, although the overall prevalence of use is lower for edibles than combustibles (Borodovsky et al., 2017; Knapp et al., 2019), cannabis consumption via edibles has increased from 2015 to 2018, while consumption through smoking has decreased (Patrick et al., 2020). Compared with inhaling, the psychoactive effects from ingestion are typically delayed and can last longer, leading to higher rates of overconsumption and accidental intoxication (Ghosh et al., 2015; Lin et al., 2022). Furthermore, edible cannabis products, packaged as sugary foods, are seen as less harmful than combustible cannabis (Nguyen et al., 2022). Notably, harm perceptions about cannabis use among adolescents and young adults have been declining during the past decade (Johnston et al., 2021; Harrison et al., 2023), which coincides with increased cannabis marketing on social media (Trangenstein et al., 2019; Whitehill et al., 2020a; Cavazos-Rehg et al., 2019). The growing industry increasingly employs youth-targeted appeals that portray cannabis products as mouthwatering foods (e.g., gummy bears, chocolates) and highlight sensory characteristics (e.g., sweet, fruity) in online marketing (Luc et al., 2020), which may have led this age group to underestimate risks (Trangenstein et al., 2019; Cavazos-Rehg et al., 2019; Whitehill et al., 2020b). Although cannabis advertising is restricted on mass media, social media remains largely unregulated, potentially contributing to a positive correlation between youth exposure to online marketing and cannabis use (Trangenstein et al., 2019; Whitehill et al., 2020a).

Moreover, pro-cannabis social influences are prevalent online, including word-of-mouth endorsements that may further amplify the impacts of increasingly aggressive online marketing. Social cues online, such as likes, comments, and testimonials, can shape normative perceptions about risk behaviors (Liu et al., 2019; Liu and Shi, 2019). Perceived social norms are a powerful motivator for behavior change among young people (Franzosi di Riva and Eck, 2018). For instance, having friends who use cannabis increases adolescents' likelihood to use it (Wang et al., 2018). Online comments and normative cues also impact youths' evaluations of anti-drug announcements, reactions to alcohol ads, and body-image perceptions on platforms like Instagram (Kim, 2021; Walther et al., 2010; Noel, 2021). Therefore, pro-cannabis comments that dominate the online commentary space, even if contributed only by a relatively small group of cannabis advocates, may lead to overestimation of prevalence and acceptance of cannabis use, which may further increase perceived product appeal and intentions for consumption. In contrast, anti-cannabis comments may mitigate marketing influences. To understand the roles of social media comments in the rising cannabis use among adolescents and young adults, our first goal is to experimentally examine the effects of pro- versus anti-cannabis comments on product appeal and intentions for cannabis use. We pose the following hypotheses and research questions related to social media comments' potential effects in amplifying online advertisements that promote edible cannabis products.

H1a-b. : In each age group, compared with participants exposed to pro-cannabis comments, those exposed to anti-cannabis comments will report lower (a) intentions to use marijuana and (b) product appeal.

H2a-b. : In each age group, compared with participants exposed to pro-cannabis comments, those exposed to no comments will report lower (a) intentions to use marijuana and (b) product appeal.

H3a-b. : In each age group, compared with participants exposed to no comments, those exposed to anti-cannabis comments will report lower (a) intentions to use marijuana and (b) product appeal.

RQ1. : Will the effects of social media comments differ by age group?

Our second goal is to examine the efficacy of cannabis health warning labels (CWLs), particularly those with enhanced text and visual depictions, in countering the influences of pro-cannabis online marketing and social media comments. Mandating CWLs on marketing materials offers a promising, cost-effective strategy to counter pro-cannabis marketing and social cues. Health warning labels have proven effective in tobacco control (Niederdeppe et al., 2019; Noar et al., 2015; White et al., 2008); however, this knowledge has not been adequately applied to redesigning CWLs in the U.S., although New York State recently required inclusion of both fixed and rotating health warnings on cannabis advertisements (New York State Office of Cannabis Management, 2023). Current CWLs are predominantly text-only, hard to read, and lack essential health information (Silver et al., 2020). Studies examining redesigned CWLs with textual (e.g., larger fonts emphasizing specific health risks) and visual enhancements (e.g., graphic portrayals) have shown improved recall of health risks and perceived message effectiveness (Goodman et al., 2019; Kim et al., 2022; Mutti-Packer et al., 2018; Pepper et al., 2020; Winstock et al., 2020). However, existing research has not systematically examined CWLs' effects against competing pro-cannabis influences prevalent online. As states consider CWL mandates, policymakers need evidence on how enhanced CWLs would perform vis-à-vis pro-cannabis influences in the complex media ecology to better understand their public health impact. This study aims to fill this gap.

H4a-b. : Compared with edible marketing posts absent of any CWLs, imposing *textual* CWLs will reduce (a) intentions to use marijuana and (b) product appeal for both age groups.

H5a-b. : Compared with edible marketing posts absent of any CWLs, imposing *pictorial* CWLs will reduce (a) intentions to use marijuana and (b) product appeal for both age groups.

RQ2. : In each age group, will pictorial warnings outperform textual warnings in reducing (a) intentions to use marijuana and (b) product appeal?

RQ3. : Will the countering effects of CWLs differ by age group?

Lastly, given the lack of prior research examining how pro- and anti-cannabis comments may amplify or weaken the effects of CWLs among at-risk adolescents and young adults, we propose to explore these interaction effects.

RQ4. : Will social media comments moderate the effects of warning labels in either age group?

2. Methods

2.1. Study design and sample

This study adopts a 3 (warning labels: no warnings vs. textual warnings vs. pictorial warnings) by 3 (comments: no comments vs. anti-cannabis comments vs. pro-cannabis comments) between-participant factorial design, plus a set-aside questionnaire control (omitted from the current manuscript as the focus here is on the effects of warning labels and social media comments). Participants were recruited from the Qualtrics online panel. Parental consent was sought for minors. Compared with representative national samples, the Qualtrics panel has similar demographic composition and produced similar prevalence estimates of past cannabis use among adolescents in prior research (Whitehill et al., 2020a). Participants were screened out if they reported "Definitely no" or "Probably no" to three screening questions (Barrington-Trimis et al., 2020): "Would you try marijuana if one of your best friends offered it to you?", "Do you think you would use marijuana in the next 6 months?", and "Are you curious about using marijuana?". A total of 2746 participants with complete data (see Table S7 in Appendix for participant characteristics) were included in the analysis, split between two age groups: adolescents (13–18 yrs., $n = 970$) and young adults (18–25 yrs., $n = 1776$).

After consenting, participants answered questions about demographics and pre-treatment covariates, including intentions to use

substances if given the opportunity, social environment related to cannabis use, exposure to cannabis ads, and behavioral activation (e.g., fun seeking). They were then randomized to one of the nine conditions with varying combinations of warning labels and social media comments (see Fig. 1 for details). Each participant was then exposed to three sets of messages.

After exposure to each set of messages, participants reported perceived product appeal specific to the product and brand promoted in the marketing post. The three product appeal ratings were averaged to form a single score per participant. After viewing all three sets of stimuli, they indicated their intentions for cannabis use. Participants in the no-warning conditions completed measures for outcome variables before proceeding to the debriefing page where the ten warning labels addressing specific cannabis health risks (Supplementary 2) were displayed.

2.2. Message stimuli

Participants were randomized to view condition-specific stimuli messages. In each condition multiple message variants were used to reduce case-category confounding (Jackson, 1992; Slater et al., 2015) and ensure effects were not specific to any individual warning, cannabis ad, or comment. Following existing protocols (Kim et al., 2022), we developed ten single-themed CWLs with textual and visual enhancements, covering approximately 30% of the marketing post (see Fig. 1 for examples). Each CWL addresses one of the following health risks supported by the current state of cannabis medical research (Volkow et al., 2016; National Academies of Sciences, Engineering, and Medicine, Health and Medicine Division, Board on Population Health and Public Health Practice, Committee on the Health Effects of Marijuana: An Evidence Review and Research Agenda, 2017) and cited in a recent California bill introducing redesigned CWLs (Pan et al., 2022): early use and cognitive function loss, driving risks, mental health issues, suicidal ideation, delayed effects, contaminants in illegal cannabis, nausea and vomiting, and risk of use during pregnancy including mother-to-baby transfer.

The study team collected 60 marketing posts promoting edibles and 200 comments (equally split between pro- and anti-cannabis) from Facebook, Reddit, and Twitter. All materials were collected in spring 2021. The study team vetted all marketing posts to ensure the presence of youth-targeted appeals, defined as portrayals that highlight thematic, visual and taste attributes (e.g., sweet, fruity) associated with sensory satisfactions. Comments were pre-processed to remove references to original authors and manually coded for valence. Each of the ten CWLs was imposed onto the set of original marketing posts to create a pool of 600 marketing posts with textual CWLs, another 600 posts with pictorial CWLs, and 60 control posts without CWLs, all high in external validity. This is the largest set of CWL stimuli and cannabis-related marketing posts ($N = 1260$) studied to date. This study design provides each participant almost a unique combination of non-redundant, randomly selected messages to reduce fatigue and improve external validity, while systematically varying the presence of manipulated CWLs and social

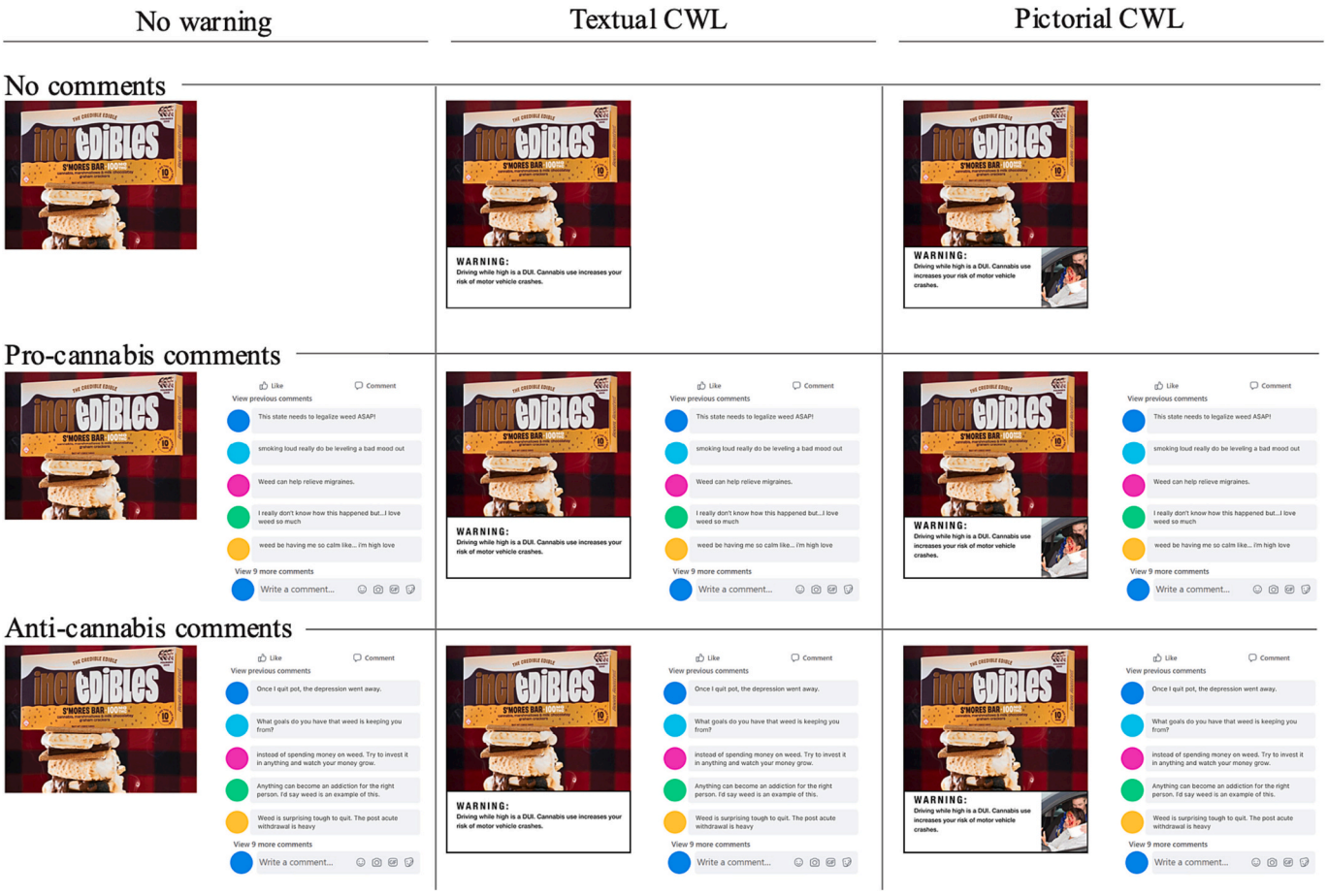

Fig. 1. Sample warning messages and social media comments.
Notes. Examples of stimuli by condition. In total, 60 marketing posts with youth-targeting appeals were used, each paired with either 10 textual warnings, 10 pictorial warnings, or no warnings (total stimuli size: $N = 1260$). Furthermore, 100 pro-cannabis and 100 anti-cannabis posts were included in the stimuli pool for social media comments. Each participant in the comments conditions was exposed to 5 randomly selected comments for each marketing post, totaling 15 comments of the same valence about cannabis use across the three exposures throughout the study.

media comments to allow valid causal inference.

2.3. Measures

Demographics. Participants provided age, race, ethnicity, gender, sexual orientation, household income, political affiliation (liberal, moderate, or conservative), and the highest educational attainment of either parent. They also indicated their state of residence, categorized as a state with or without legalized non-medical cannabis.

Social environment. Participants reported the number of friends who regularly use cannabis for fun, ranging from *1 = none* to *5 = almost all*.

Past exposure to cannabis ads. Participants indicated how often they saw ads for cannabis products or businesses in the past three months, ranging from *1 = Never* to *4 = Five times or more*, in various channels (Tveleneva et al., 2022). Responses were averaged (Cronbach's α = 0.74; adolescents: M = 2.49, SD = 0.89; young adults: M = 2.38, SD = 0.84).

Behavioral Activation. Behavioral activation such as fun seeking serves as a motivator for individuals to achieve goal-oriented outcomes and is highly relevant to self-regulation (Carver and White, 1994). Participants responded to four questions on a scale from *1 = very false* to *4 = very true*, asking if they are willing to try something new for fun, how often they do things just for fun, acting on the spur of the moment, and craving excitement and new sensations (Cronbach's α = 0.78; adolescents: M = 3.09, SD = 0.61; young adults: M = 2.78, SD = 0.72).

Intention to use cannabis. Participants rate their intent to use "any marijuana" on a three-item scale (*1 = Definitely no*, *4 = Definitely yes*), including using it if given the chance this weekend, in the next three months, or if close friends offered it (Cronbach's α = 0.90; adolescents: M = 2.77, SD = 0.89; young adults: M = 2.89, SD = 0.92).

Product appeal. For each marketing post, participants rated product ads on a six-item semantic differential scale (e.g., *not appealing* vs. *appealing*, *bad* vs. *good*, *worthless* vs. *valuable*), with responses ranging between −2 and + 2. First, ratings of these attributes were averaged to form a single product appeal for each of the three marketing posts. Then, the three product appeal scores were averaged again across the three marketing posts to form an overall product appeal score for each participant (Cronbach's α = 0.95; adolescents: M = 0.30, SD = 0.94; young adults: M = 0.60, SD = 1.04), which was analyzed in subsequent regression models.

2.4. Statistical analyses

To maximize statistical power, we analyzed the combined sample while including interaction terms between condition dummies and age group to estimate subgroup effects. We used R's *emmeans* package to estimate marginal means and between-condition contrasts for each age group, and the robust "sandwich" estimator for standard errors and 95% confidence intervals. The Holm method was used throughout to adjust for family-wise error rate. All tests were two-tailed. We report unconditional models without covariates in the main manuscript because unconditional models tend to produce more conservative estimates for randomized experiments. We present conditional models that included all covariates in Supplementary Materials (see Table S5-S6). The results remain similar and hence were omitted from the main manuscript.

Replication data files, R codes, message stimuli, and measures can be found in an online OSF depository (link: https://osf.io/4zp6a/?view_only=e93766a8d1be4ef9a4f0d4260396540d). The study protocol was approved by the Institutional Review Board of the corresponding author's institution.

3. Results

The sample of young adults (n = 1776) was more diverse with regards to key sociodemographic characteristics than the adolescent sample (n = 970), with differences noted in gender (56.9% of young adults vs. 47.3% of adolescents self-identified as women), race (30.6% vs. 10.2% as Black), ethnicity (24.8% vs. 21.0% as Hispanic), sexual orientation (35.8% vs. 12.0% as LGBTQ+), and household income (46.0% vs. 19.9% below $35,000). In both groups, slightly fewer participants resided in states where non-medical cannabis had been legalized (42.1% of young adults and 43.3% of adolescents). For a detailed breakdown of the sample characteristics, please refer to Table S7 in the Supplementary Materials.

3.1. Effects of pro- and anti-cannabis comments

First, among adolescents, cannabis use intention differed by social media comments, $F(2, 2740) = 3.23$, $p = .040$ (see Table 1). Anti-cannabis comments significantly decreased intention compared to pro comments ($b = -0.17$, 95% CI [−0.32, −0.01], $p = .031$). No significant difference was found comparing no comments to either anti- or pro-cannabis comments. For young adults, comments did not affect cannabis use intention. No significant interactions existed between age

Table 1
Impact of Cannabis Warning Labels and Social Media Comments on Intention to Use Cannabis by Age Group, United States: 2022.

	Intention to use Cannabis			
	Adolescents (age: 13–17)		Young adults (age: 18–25)	
	Main effects *b* [95% CI]	Interaction effects *b* [95% CI]	Main effects *b* [95% CI]	Interaction effects *b* [95% CI]
Cannabis warning labels				
No warning message	–	–	–	–
P: Pictorial (vs. none)	**−0.30 [−0.46, −0.14]**	**−0.34 [−0.56, −0.12]**	**−0.18 [−0.30, −0.06]**	**−0.21 [−0.39, −0.04]**
T: Textual (vs. none)	**−0.20 [−0.35, −0.04]**	**−0.3 [−0.51, −0.10]**	**−0.15 [−0.27, −0.03]**	**−0.24 [−0.41, −0.06]**
Main effects: Overall F-test	***F (2, 2740) = 10.03 p < .001***		***F (2, 2740) = 7.12 p < .001***	
Social media comments				
Pro-cannabis comments	–	–	–	–
A: Anti-cannabis comments (vs. pro)	**−0.17 [−0.32, −0.01]**	**−0.22 [−0.42, −0.02]**	−0.03 [−0.15, 0.09]	−0.16 [−0.33, 0.01]
N: No comments (vs. pro)	−0.12 [−0.28, 0.04]	−0.19 [−0.39, 0.01]	−0.02 [−0.14, 0.10]	0.01 [−0.15, 0.17]
Main effects: Overall F-test	***F (2, 2740) = 3.23 p = .040***		*F (2, 2740) = 0.15 p = .858*	
Warnings x comments				
P x A		0.13 [−0.20, 0.46]		0.24 [−0.01, 0.49]
T x A		0.11 [−0.20, 0.43]		0.18 [−0.07, 0.43]
P x N		0.03 [−0.31, 0.37]		−0.15 [−0.39, 0.10]
T x N		0.26 [−0.06, 0.59]		0.08 [−0.16, 0.33]
Interaction effects: Overall F-test		*F (4, 2728) = 0.86 p = .488*		***F (4, 2728) = 2.68 p = .030***

Notes. No covariates were included. Main effects of warning labels and comments were separately estimated. Age group specific effects were estimated using the *emmeans* package in *R*. Robust standard errors were used to estimate 95% CIs. Holm adjustment was performed to control for family-wise error rate. All tests were two-tailed. Significant effects were bolded.

groups and comments conditions.

Second, regarding product appeal, pro-cannabis comment (vs. no comments) increased product appeal to a larger degree among adolescents than young adults (moderation by age group: $b = 0.25$, 95% CI [−0.44, −0.05], $p = .011$). Among adolescents, product appeal ratings differed across comment conditions, $F(2, 2740) = 4.10$, $p = .017$. Adolescents reported lower product appeal after seeing anti-cannabis comments ($b = -0.18$, 95% CI [−0.35, −0.00], $p = .025$) or no comments ($b = -0.21$, 95% CI [−0.40, −0.03], $p = .021$, see Table 2) compared to pro-cannabis comments. There was no significant difference between anti-cannabis comments and no comments conditions. Among young adults, there was also an overall main effect of comments, $F(2, 2740) = 7.22$, $p < .001$. Young adults reported lower product appeal after seeing anti-cannabis comments compared to pro-cannabis comments ($b = -0.16$, 95% CI [−0.28, −0.04], $p = .008$), with no significant differences when compared to no comments. Anti-cannabis comments also reduced product appeal (vs. no comments, $b = -0.19$, 95% CI [−0.31, −0.09], $p < .001$).

Table 2
Impact of Cannabis Warning Labels and Social Media Comments on Product Appeal by Age Group, United States: 2022.

	Product appeal			
	Adolescents (age: 13–17)		Young adults (age: 18–25)	
	Main effects *b* [95% CI]	Interaction effects *b* [95% CI]	Main effects *b* [95% CI]	Interaction effects *b* [95% CI]
Cannabis warning labels				
No warning message	–	–	–	–
P: Pictorial (vs. none)	**−0.20 [−0.39, −0.02]**	−0.17 [−0.43, 0.08]	**−0.18 [−0.30, −0.06]**	−0.08 [−0.26, 0.10]
T: Textual (vs. none)	−0.12 [−0.30, 0.06]	−0.23 [−0.47, 0.01]	**−0.12 [−0.24, −0.00]**	−0.16 [−0.34, 0.02]
Main effects: Overall F-test	***F (2, 2740) = 3.15 p = .043***		***F (2, 2740) = 5.53 p = .004***	
Social media comments				
Pro-cannabis comments	–	–	–	–
A: Anti-cannabis comments (vs. pro)	**−0.18 [−0.35, −0.00]**	−0.21 [−0.46, 0.04]	**−0.16 [−0.29, −0.04]**	−0.17 [−0.36, 0.01]
N: No comments (vs. pro)	**−0.21 [−0.40, −0.03]**	**−0.26 [−0.51, −0.02]**	0.04 [−0.08, 0.16]	0.12 [−0.06, 0.29]
Main effects: Overall F-test	***F (2,2740) = 4.10 p = .017***		***F (2,2740) = 7.22 p < .001***	
Warning x comments				
P x A		0.04 [−0.33, 0.42]		−0.06 [−0.33, 0.21]
T x A		0.09 [−0.28, 0.47]		0.11 [−0.15, 0.36]
P x N		−0.07 [−0.47, 0.33]		−0.24 [−0.5, 0.01]
T x N		0.29 [−0.09, 0.67]		0.01 [−0.24, 0.26]
Interaction effects: Overall F-test		*F (4, 2728) = 0.88 p = .473*		*F (4,2728) = 1.39 p = .233*

Notes. No covariates were included. Main effects of warning labels and comments were separately estimated. Age group specific effects were estimated using the *emmeans* package in *R*. Robust standard errors were used to estimate 95% CIs. Holm adjustment was performed to control for family-wise error rate. All tests were two-tailed. Significant effects were bolded.

H1b was supported by the data, while H1a, H2b, and H3b were partially supported. H2a was not supported. Although there was no significant evidence for moderation by age group, pro-cannabis comments (vs. anti-cannabis comments) significantly increased intentions for cannabis use only among adolescents (RQ1). See Fig. 2 for a visual summary.

3.2. Effects of cannabis warning labels

First, CWLs affected intentions for cannabis use (see Table 1) both for adolescents, $F(2, 2740) = 10.03$, $p < .001$, and young adults, $F(2, 2740) = 7.12$, $p < .001$, although age group did not moderate the effects of CWLs. Among adolescents, compared to no warnings, textual ($b = -0.20$, 95% CI [−0.35, −0.04], $p = .004$) and pictorial ($b = -0.30$, 95% CI [−0.46, −0.14], $p < .001$) warnings significantly reduced intentions. For young adults, similarly, textual ($b = -0.15$, 95% CI [−0.27, −0.03], $p = .005$) and pictorial ($b = -0.18$, 95% CI [−0.30, −0.06], $p = .001$) warnings both decreased intentions. Pictorial and textual warnings did not significantly differ in either age group.

Second, regarding product appeal, CWL effects did not differ by age group but were significant for both adolescents, $F(2, 2740) = 3.15$, $p = .043$, and young adults, $F(2, 2740) = 5.53$, $p = .004$ (see Table 2). Pictorial but not textual warnings reduced appeal for adolescents ($b = -0.20$, 95% CI [−0.39, −0.02], $p = .028$). For young adults, both pictorial ($b = -0.18$, 95% CI [−0.30, −0.06], $p = .002$) and textual warnings ($b = -0.12$, 95% CI [−0.24, −0.00], $p = .029$) reduced product appeal. No significant differences between textual versus pictorial CWLs were found in either age group.

Hence, H4a and H5a-b were supported by the data, while H4b was partially supported. Evidence of superiority of pictorial warnings over textual warnings (RQ2) was not statistically significant. The countering effects of CWLs did not significantly differ by age group (RQ3). See Fig. 2 for a visual summary.

Regarding RQ4, we did not find any significant interaction effects between specific warning labels and comments conditions for either outcome, respectively for each age group, despite a significant omnibus test on intention among young adults, $F(4, 2736) = 2.68$, $p = .030$.

4. Discussion

As perceptions of harm from cannabis use decline and early initiation increase in youth and young adults (Johnston et al., 2019; Lee et al., 2021; Lipari, n.d.), identification of online risks and of cost-effective interventions for these susceptible groups are urgent public health challenges. In a national online experiment, we examined online marketing posts promoting marijuana edibles with youth-targeting appeals that highlight sensory appeals, such as candy/chocolate-like portrayals and fruity flavors, using an ecologically valid stimuli pool. Our results revealed that pairing youth-targeted marketing with pro-cannabis comments, widely found on social media, increased product appeal among adolescents. We did not observe similar amplification effects for young adults, though a formal interaction test did not support significant differences in effect size between age groups. This finding aligns with previous research on teens' susceptibility to normative influences on substance use (Liu et al., 2019; Liu and Shi, 2019; Wang et al., 2018; Kim, 2021; Walther et al., 2010; Noel, 2021). We extend this research by showing asymmetric influences of online comments on cannabis products, where anti-cannabis comments (vs. no comments) did not reduce product appeal or intentions. For regulators and substance prevention researchers, these findings highlight the need to consider the competitive online environment that adolescents and young adults encounter daily, where preventive communication programs must compete with online pro-cannabis marketing and user-contributed endorsements.

We then tested the effectiveness of re-designed CWLs', incorporating textual and pictorial enhancements in a realistic competitive

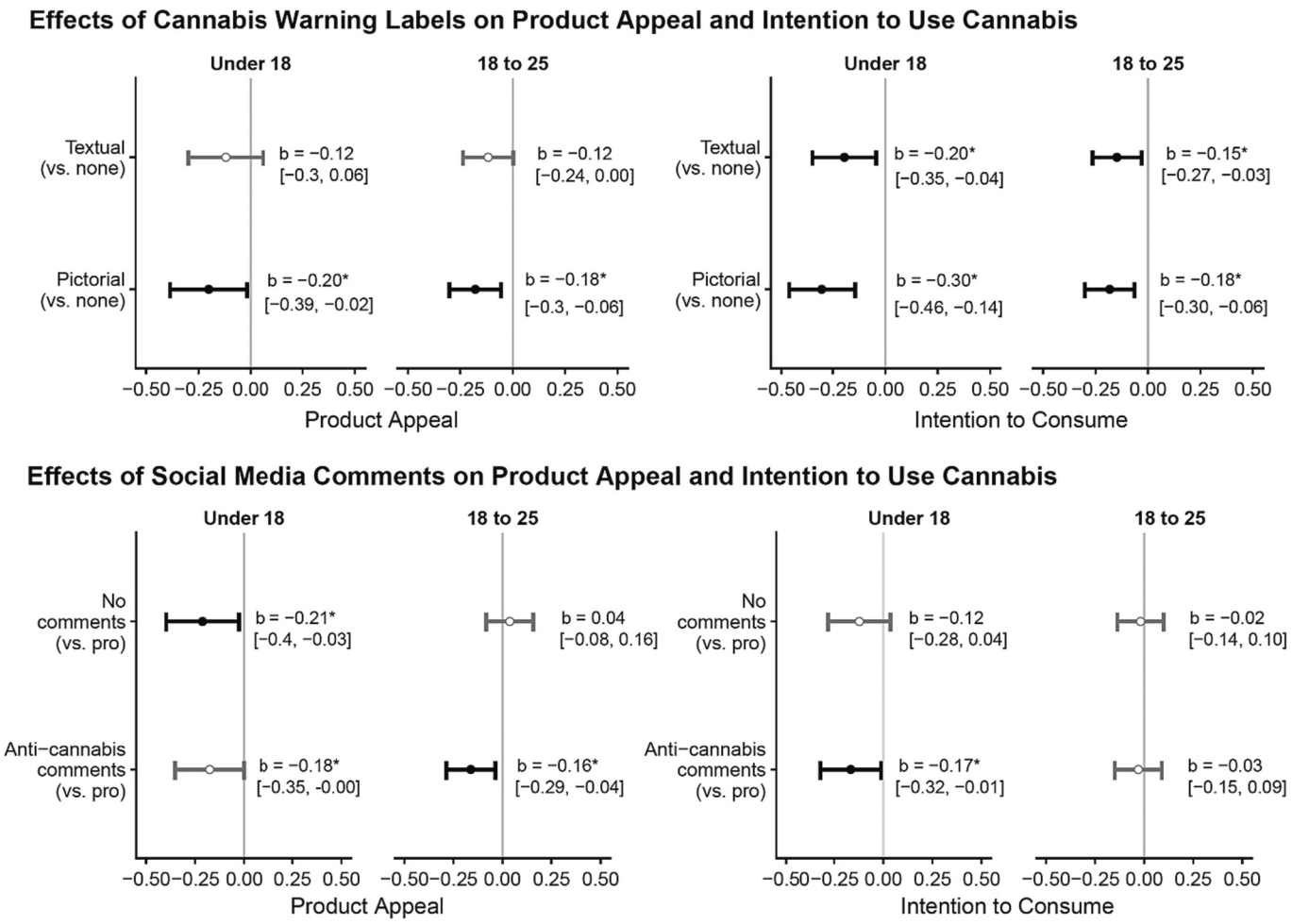

Fig. 2. Main Effects of Cannabis Warning Labels and User-Contributed Comments on Product Appeal and Intention for Cannabis Use by Age Group, United States: 2022.

Notes. No covariates were included. Main effects of warning labels and comments were separately estimated. Age group specific effects were estimated using the *emmeans* package in *R*. Robust standard errors were used to estimate 95% CIs.

informational environment with youth-targeted marketing and online social cues. Although California considered mandating enhanced pictorial CWLs (Pan et al., 2022) on products and advertisements in 2022[49] and other states may follow, empirical evidence assessing their efficacy in the competitive social media environment is lacking. Our study demonstrated that both textual and pictorial redesigned CWLs effectively reduced product appeal and intentions for cannabis use when imposed on youth-targeted marketing posts, consistent across age groups. CWLs' countering effects remained robust in reducing intentions for cannabis use, even when pro-cannabis comments accompanied youth-appealing marketing posts (*b*s range: −0.21 to −0.34 on a 4-point scale, all *p*s < 0.05 after Holm adjustment). Previous research tends to test CWLs (Goodman et al., 2019; Kim et al., 2022; Mutti-Packer et al., 2018; Pepper et al., 2020; Winstock et al., 2020) without considering pro-cannabis social cues prevalent on social media. Our findings extended this line of research by providing new evidence on the efficacy of enhanced CWLs in countering a large, realistic set of youth-targeting online advertisements and user endorsements among adolescents and young adults. As regulators weigh preventive interventions amid expanding legalization, these results support requiring effectively designed CWLs on online marketing materials to protect susceptible adolescents and young adults, a potentially low-cost and high reach policy.

This study has limitations. First, we assessed self-reported intentions in a one-time exposure online experiment rather than tracking actual cannabis use behaviors over time. That said, a recent meta-analysis showed that self-reported intentions can provide as good diagnostic signals as actual behaviors for evaluating message-based interventions (O'Keefe, 2021). Second, we focused only on marketing posts promoting edibles and our intention measures did not specify route of administration. Future research should extend to consider other types of cannabis products. Finally, our national sample, though diverse in key demographics, was not probabilistic.

5. Conclusion

In a national experiment, we found that pro-cannabis online comments increased product appeal in youth-targeting cannabis online ads, increasing the risk for early and/or habitual cannabis use among adolescents. Using enhanced CWLs helped counter online pro-cannabis marketing and social influences, reducing product appeal and intentions for cannabis use among both adolescents and young adults. Findings suggest that implementing enhanced CWLs on advertising can help reduce cannabis use among youth in the competitive online informational environment.

CRediT authorship contribution statement

Sijia Yang: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project

administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Lynne M. Cotter:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Linqi Lu:** Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Lauren A. Kriss:** Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Matt Minich:** Conceptualization, Data curation, Investigation, Writing – original draft, Writing – review & editing. **Jiaying Liu:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing. **Lynn D. Silver:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing. **Christopher N. Cascio:** Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

All authors have no conflict of interest to disclose.

Data availability

Replication data files, R codes, message stimuli, and measures can be found in an online OSF depository (link: https://osf.io/4zp6a/?view_only=e93766a8d1be4ef9a4f0d4260396540d).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2024.107877.

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