First Comes Substance Use, Then Comes Social Media Posts?
Examining the Temporal Ordering and Relative Strength of Relations Across Alcohol,
Tobacco and Marijuana Use and Posting Behavior

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Conflict of interest

The authors report no conflict of interest.

Abstract

Social media posts represent a major route by which youth share their substance use cognitions and experiences with others. Extant research has primarily examined relations between alcohol-related posts and posters' own alcohol use, yet little is known about the role of social media in the use of less socially accepted substances, namely tobacco and marijuana. Our study represents the first to examine the relative strength of this relation across alcohol, tobacco, and marijuana. The current research used a one-month time lag to tease apart the temporal ordering of substance-use-posting and participants' own substance use. A sample of 282 15-20-year-olds (Mage = 18.4, SD = 1.3, 52.9% female) in the United States completed two self-report surveys, one month apart. Results of a cross-lagged panel model revealed significant effects of alcohol and marijuana consumption on subsequent alcohol- and marijuana-related posting, respectively (i.e., *selection effects*). However, reverse relations (i.e., *self-effects*) were not significant. Further, we found no differences in the strength of selection effects across substances, suggesting they are similar for both more (alcohol) and less (marijuana and tobacco) socially acceptable substances. Results point to the importance of using young people's social media posts as a way to help identify individuals at risk for heightened substance use and social media as a mechanism for targeted prevention programming.

Keywords: alcohol, tobacco, marijuana, self-effects, social media effects, media selection

Introduction

With the habituation of social media in young people's social lives, substance use behaviors have increasingly found their way online (Groth et al., 2017; Zhang et al., 2020; Litt et al., 2018). Substance use references on social media primarily consist of pictures, video clips, or status updates, in which substance use is shown. Over the past decade, a growing number of studies have demonstrated that the sharing of and exposure to alcohol references on social media are associated with greater levels of alcohol consumption (Geusens & Beullens, 2017b, 2021c; Litt et al., 2018; Vranken et al., 2020). An important gap in this field is that most empirical studies on substance-use-related social media effects focus on alcohol. Nevertheless, this is clearly *not* the only substance individuals use offline and talk about online (Groth et al., 2017; Moreno et al., 2016; Washington State Health Care Authority et al., 2019). To date, it remains unclear whether substance-use-related social media effects are equivalent across different types of substance use with differing levels of social acceptability. This study aims to directly address this gap, testing whether the associations between sharing about substance use on social media and offline substance use differs for alcohol, tobacco, and marijuana. Testing the equivalence of these substance-use-related social media effects will significantly add to our understanding of how social media can play different or similar roles in individuals' substance use depending on the substance use under consideration.

A second research gap relates to the timeframe wherein substance-use-related social media effects occur. Most studies on substance-use related social media effects either look at this cross-sectionally (e.g., Vranken et al., 2020), or use very long one-year time lags (e.g., George et al., 2021). Although one-year time lags seem standard in this line of research (e.g., Erevik et al., 2017; Geusens & Beullens, 2021b; Moreno et al., 2021), adolescents and emerging adults are still developing at a relatively rapid pace, with many biopsychosocial changes taking place within a one-year timespan (Arnett, 2013). Moreover, media use can

drastically change as adolescents develop into emerging adults (Coyne et al., 2019), and as certain platforms increase in popularity while others decrease (Vandendriessche & De Marez, 2020). Thus, behavior that individuals engaged in a year ago may no longer be relevant in their current decision-making processes. Recently, Geusens and Beullens (2021b) questioned within which time frames substance-use related social media effects are actually taking place, and called to test shorter time frames than the one-year time lags often used in longitudinal research. Our study aims to fill this gap by testing the appropriateness of using a one-month time lag, which allows for substance-related social media self-effects to be tested within a relatively short and developmentally appropriate timeframe.

Substance Use and Social Media Self-Effects

In the past decade, dozens of studies on the role of social media in substance use have been published. In particular, the field of *alcohol*-related social media effects is now well developed with research generally finding that exposure to alcohol posts on social media (e.g., a friend sharing a picture from a party with alcohol visible or an influencer promoting a brand of vodka) is related to more positive alcohol-related cognitions (e.g., attitudes, intentions to drink), increased alcohol consumption and increased risky drinking behavior, such as binge drinking (e.g., Groth et al., 2017; Vranken et al., 2020). Simultaneously, sharing posts about alcohol has also been linked with heavier drinking behavior among the content creators themselves (e.g., Erevik et al., 2017; Geber et al., 2021; Geusens et al., 2020; Geusens & Beullens, 2021a; Litt et al., 2018). These *self*-effects, or how sharing specific content on social media affects the content creators themselves, will be the focus of the present study.

Self-effects research builds on theories such as identity shift (Carr et al., 2021) to argue that how an individual presents themselves online can have repercussions for how they view themselves and behave. In particular, these theories argue that individuals can internalize their (online) self-presentations and unwittingly shift their cognitions and behaviors to be more in

line with these self-presentations (Carr et al., 2021). In the context of substance use, this means that by sharing substance-use-related content on social media, individuals can come to accept substance use behaviors as part of who they are, and inadvertently increase their substance use. In line with the theory, prior longitudinal research has demonstrated that sharing posts about alcohol on social media can result in heavier drinking behavior (e.g., Geber et al., 2021; Geusens & Beullens, 2017b) and higher alcohol dependence scores (e.g., Erevik et al., 2017).

However, it has also been argued that the association between communicating about substance use on social media and offline substance use may not necessarily reflect a unidirectional media effect (Geber et al., 2021; Geusens & Beullens, 2017b, 2021b). Prior research has found reciprocal relationships between communicating about alcohol on social media and offline alcohol use (Geber et al., 2021; Geusens & Beullens, 2017b). This means that individuals share more substance-use-related posts because they are consuming these substances more often (i.e., a media selection effect), but simultaneously, because they are sharing more substance-use-related content on social media, they also increase their subsequent offline substance use (i.e., a media socialization effect). In other words, individuals' social media communication both reflects and shapes their offline cognitions and substance use behaviors simultaneously.

This line of research builds on theoretical frameworks such as Slater's (2015) reinforcing spirals model. This model was originally developed to explain the relationship between exposure to media content and viewers' attitudes, identity, and behaviors. In short, this theory states that individuals select specific media content because this is in line with preexisting cognitions and behaviors. In turn, by consuming this selected media content, viewers' cognitions and behaviors can be reinforced. While none of the studies that tested a reciprocal relationship between sharing substance-use-related communication on social media and offline substance use explicitly set out to test the reinforcing spirals model, the idea that

individuals communicate online about their substance use behaviors, and this in turn potentially increases substance use seems to be in line with what research is finding (Geber et al., 2021; Geusens & Beullens, 2017b). Therefore, following Slater's (2015) reinforcing spirals model and prior findings on the reciprocity of alcohol-related social media self-effects (Geber et al., 2021; Geusens & Beullens, 2017b), we hypothesize that individuals share more substance use references as a result of their substance use (Hypothesis 1a), and simultaneously, engage in heavier substance use behaviors as a result of their online substance-use-related communication (Hypothesis 1b).

Different Substances, Different Effects?

The core of this study revolves around the question of whether previously observed alcohol-related social media effects can be generalized to other substances. As noted previously, most of the research on substance-use-related social media effects has been conducted in the field of *alcohol*-related social media effects. Only a handful of studies have looked at other substances, especially when examining self-effects. (Cabrera-Nguyen et al., 2016; Clendennen et al., 2020; George et al., 2021; Moreno et al., 2018; Unger et al., 2018). To the best of our knowledge, there are only five studies examining substance-use related social media self-effects that study tobacco and marijuana use published at the time of writing this manuscript. In comparison, the authors have identified over 30 studies examining the self-effects of communicating about alcohol on social media, many of them discussed throughout this manuscript. Considering the rich research tradition of alcohol-related social media self-effects, compared to the underdeveloped lines of research on tobacco- and marijuana-related social media self-effects, an important question arises on whether we can consolidate these lines of research to systematize and extend the scattered research efforts of the three fields and come to a more general line of *substance-use*-related social media effects.

According to theoretical models, such as the Differential Susceptibility to Media Effects Model (Valkenburg & Peter, 2013), the strength of the effect of media use on individuals' cognitions and behaviors is dependent on individual-difference (e.g., gender) and social-context variables, such as the societal acceptability of the behavior under consideration. These susceptibility factors influence how individuals interpret and respond to their media use, and consequently how strongly they are affected by this media use. Societally, alcohol is viewed differently than tobacco and marijuana use. At least in western societies, alcohol use is considered a normal and socially accepted behavior, much more so than tobacco and marijuana use (Coughenour et al., 2021). Those who use marijuana and tobacco report feeling stigmatized for their substance use, and receiving criticism from family, employers and strangers because they smoke tobacco or marijuana (Asbridge et al., 2016). It is thus unsurprising that adolescents are more likely to try alcohol than marijuana or tobacco while in high school (Keyes et al., 2019), a trend which continues in college, as more students report to drink alcohol than smoke marijuana or cigarettes (Skidmore et al., 2016).

These differences in societal norms surrounding substance use beget the question of how generalizable substance-use-related social media effects are across different substances. Research on alcohol-related sharing behavior on social media argues that many individuals don't really think about the fact that alcohol is present in their posts (Hendriks et al., 2017) and that sharing alcohol-related content on social media "is so socially acceptable that little thought [is] given to it at the moment of sharing" (Geusens & Beullens, 2021c, p. 9). In contrast, older work on substance use references on social media have found that marijuana posts are considered less socially acceptable than alcohol posts (Morgan et al., 2010). Yet, qualitative research among high schoolers (aged 13-19) found that adolescents consider social media posts depicting tobacco or marijuana 'cool' and a status symbol (Liu et al., 2020), something which very few individuals argue to be a motivation for depicting alcohol on social media (Hendriks

et al., 2017). These studies suggest that alcohol posts may hold a different meaning to the content creators than marijuana or tobacco posts.

Currently, it is unclear whether we should expect the effects of communicating about different substances to be equivalent. The two studies that have compared different substances provide mixed results: whereas Cabrera-Nguyen et al. (2016) findings point towards potential generalizability of alcohol- and marijuana-related social media self-effects, findings of George et al. (2021) support the opposite. Understanding to what extend findings from the research on alcohol-related social media effects can be extended to tobacco- and marijuana-related social media effects will allow for these fields to build on each other's work, rather than work in silos. In addition, research on alcohol-related social media effects has already informed alcohol interventions to incorporate social media facets (e.g., Litt et al., 2022). This consolidation of the research will help us inform tobacco and marijuana interventions as well, as well as help us understand where it would be most impactful to focus if funding is limited. Therefore, we will test the equivalence of substance-use-related social media self-effects across three substances with differing societal norms: alcohol, tobacco and marijuana. In particular, this study will examine whether the reciprocal relationship between sharing posts about substances on social media and offline substance use (see: Hypothesis 1) is similar for alcohol, tobacco, and marijuana use (Research Question).

Method

Sample

Data were collected from March 2017 to April 2018 as part of a larger longitudinal experimental study designed to understand associations between alcohol displays on social media and alcohol cognitions, drinking behavior, and negative consequences among a sample of 15-20-year-olds. This study conducts secondary analyses on the baseline and 1-month follow-up data, controlling for the experimental conditions. A second paper (Litt et al., under

review) using these data focuses on the experiment itself, and is currently under review. The aim of the original experiment was to examine whether exposure to social media profiles in which the drinking norm was manipulated would affect participants' alcohol-related descriptive and injunctive normative perceptions and drinking behavior. Participants were randomly assigned to one of three conditions in which they viewed a series of researcher-fabricated social media profiles: 1) abstaining/drinking condition: individuals were exposed to social media profiles that contained references to using alcohol and social media profiles that contained references to abstaining from alcohol; 2) Abstaining-only condition: individuals were exposed to social media profiles that contained references to abstaining from alcohol; and 3) Control condition: individuals were exposed to social media profiles that did not contain any alcohol- or abstainer-related content. In the current paper, we control for the condition individuals were assigned to (see: Measures).

Recruitment efforts for this study were conducted locally in the Seattle-metro area using a variety of methods including online and print advertisements, friend referrals, university registrar's list, and in-person flyering. Eligibility criteria for the larger study included: 1) be age 15 to 20 years old, 2) live in the Seattle-metro area, 3) drink at least once within the past 6 months (applied only to 18-20-year olds), 4) use Facebook, Snapchat, or Instagram at least weekly, and 5) be willing to attend two in-person sessions as part of the larger experimental study. Eligible participants were invited to schedule the first of two in-person sessions at the lab, where they completed a baseline survey prior to completing the experimental paradigm. Participants who completed the baseline survey were compensated $30 for their time and participants who completed the 1-month follow-up were paid $45 for their time.

A total of 1,017 individuals completed screening and 543 (53.4%) were eligible for the larger study. Out of the 543 participants who met initial screening criteria, 344 successfully completed a phone verification call (63.3%), and of those individuals, 306 (88.9%) completed

the baseline survey and in-person session. At baseline, participants were on average 18.4 years old ($SD = 1.3$) and 47.1% were male. At baseline, 55.9% reporting being Caucasian/White, 27.5% Asian, 10.1% more than one race, 3.3% Black, and 2.3% other; 9.2% identified as Hispanic/Latino. Approximately, 78.7% of our sample were current college students, 19% were high school or running start students, 0.6% were in a different schooling program (i.e., pursuing a GED or vocational school), and 1.6% were not in school. We retained 282 participants at the 1-month follow-up data collection (retention rate = 92.16%), as 24 participants dropped out of the study between the baseline survey and in-person session and follow-up measurement one month later.

Measures

   Substance use. Participants were asked to respond to an item adapted from the Daily Drinking Questionnaire (Collins et al., 1985) that read "On average, during the past month, how often have you consumed" (a) alcohol, (b) tobacco, and (c) marijuana or cannabis. Answer options ranged from (0) never or did not use in the past month, to (11) more than once per day. This question was asked both at baseline and 1-month follow-up.

   Substance use posts. Participants were asked a parallel question to the Daily Drinking Questionnaire that read "How often do you post something (wall posts, comments, statuses, pictures, etc.) on social networking sites that mentions or shows you" (a) drinking alcohol, (b) smoking tobacco, or (c) using marijuana. Answers could range from (0) never, to (8) every day, but were recoded to (0) never and (1) at least once due to the low variability in answers. This question was asked both at baseline and 1-month follow-up.

   Control variables. We controlled for birth sex (0 = female, 1 = male), age at baseline (open question), and the experimental condition. The experimental conditions were entered as two dummy variables: abstaining versus control and abstaining/drinking versus control. All control variables were measured at baseline only. Sex and age were controlled for because of

the gender double standard for substance use and online substance-use-related communication, and the likelihood of substance use and social acceptability of substance-use-related communication increasing with age (Keyes et al., 2019; Vranken et al., 2023).

Analyses

First, SPSS version 27 was used for the preliminary statistics, after which we tested a cross-lagged panel model simultaneously testing the cross-lagged relationships between substance use and substance use sharing for alcohol, tobacco and marijuana use in Mplus version 8 (Muthén & Muthén, 2017). The model was bootstrapped (1000 samples) to account for potential nonnormality of the data (Russell & Dean, 2000) and missing data was handled using pairwise deletion, the default setting in Mplus. Model fit was decided upon inspection of the comparative fit index (CFI, >.95), Tucker-Lewis index (TLI, >.95), root mean square error of approximation (RMSEA, <.06), and standardized root mean squared residual (SRMR, <.08) (Hu & Bentler, 1999). All variables were entered as manifest variables, conspiring that they were single items. We controlled for age, sex and the original experimental conditions (two dummy variables) by regressing the six outcome variables on the four control variables.

To test our research question, we constrained the relationships of interest to be equal, and used nested-model Chi²-difference testing to test whether the differences were significant. In particular, two constrained models were tested. First, we tested whether the associations between alcohol use at baseline and alcohol posts one month later, marijuana use at baseline and marijuana posts one month later and tobacco use at baseline and tobacco posts one month later could be constrained to be equal. Then, we tested whether the associations between alcohol posts at baseline and alcohol use one month later, marijuana posts at baseline and marijuana use one month later, and tobacco posts at baseline and tobacco use one month later could be constrained to be equal. In line with recommendations by Asparouhov (Mplus Discussion Board, 2015), the models were re-run with full information maximum likelihood

(FIML) estimation with robust standard errors (MLR) to conduct Satorra-Bentler scaled Chi² difference testing. Before testing the hypotheses, we conducted a multivariate analysis of variance (MANOVA) using Pillai's trace to assess whether attrition may have biased our final sample. The analysis indicated that there were no significant differences in age, birth sex, substance use or substance use posting between those who participated in the follow-up measurement and those who didn't (Pillai's Trace = .02, $F(8,291)$ = .71, p = .68).

Results

Descriptive Results

On average, participants drank alcohol about three times during the past month (See Table 1 for a complete overview of the substance use patterns). A minority of our sample did not drink alcohol in the past month, but more than a quarter of the sample consumed alcohol more than once per week (31.7% at baseline, 27.5% at follow-up). Tobacco use was less common: approximately three quarters of our sample did not use tobacco during the past month, and most participants who did use tobacco, did so only once during the past month (9.8% at baseline, 9.7% at follow-up). Approximately 5% of the individuals in our sample used tobacco more than once per week (5.2% at baseline, 5.8% at follow-up). On average, participants used tobacco less than once per month. Finally, approximately half our sample used marijuana in the past month, and approximately one in ten used marijuana more than once per week (11.3% at baseline, 13.3% at follow-up). On average, participants used marijuana nearly twice per month. See Table 2 for an overview of the zero-order correlations.

TABLE 1 ABOUT HERE

When looking at substance use sharing patterns on social media, most participants did not share substance use references. Approximately one in three participants shared alcohol references (34.4% at baseline, 31.0% at follow-up), almost no one shared tobacco references

(5.0% at baseline, 4.7% at follow-up) and one in seven participants shared marijuana references (16.3% at baseline, 14.2% at follow-up).

TABLE 2 ABOUT HERE

Hypothesis Testing

Our cross-lagged panel model had good fit (χ^2 =51.57, df = 24, p < .001, RMSEA = .06, CFI = .98, TLI = .93, SRMR = .04). Hypothesis 1 predicted that individuals share more substance use references as a result of their substance use (H1a), and simultaneously, engage in heavier substance use behaviors as a result of their online substance-use-related communication (H1b). This hypothesis was only partially supported. Contrary to our expectations (H1b), we did not find substance use sharing on social media to predict substance use one month later, neither for alcohol (β = .03, SE = .05, p = .60, Boot 95% LLCI/ULCI = -.08/.17), tobacco (β = .01, SE = .07, p = .92, Boot 95% LLCI/ULCI = -.13/.14) or marijuana (β = .08, SE = .06, p = .23, Boot 95% LLCI/ULCI = -.05/.20). However, in line with our expectations (H1a), we did find that alcohol consumption predicted sharing posts about alcohol one month later (β = .16, SE = .05, p = .001, Boot 95% LLCI/ULCI = .06/.26), and marijuana use predicted sharing posts about marijuana one month later (β = .25, SE = .07, p = .001, Boot 95% LLCI/ULCI = .09/.38). For tobacco, this relationship was non-significant (β = .13, SE = .08, p = .11, Boot 95% LLCI/ULCI = -.02/.29). See Figure 1 for an overview of all significant associations and Appendix A for the full SEM results.

FIGURE 1 ABOUT HERE

Additional χ^2-difference tests demonstrated the associations between alcohol use and sharing alcohol posts one month later, tobacco use and sharing tobacco posts one month later, and marijuana use and sharing marijuana posts one month later are equal in strength ($\Delta\chi^2$ = 1.16, p = .17). Likewise, the non-significant relationships between sharing alcohol posts, tobacco posts and marijuana posts and their corresponding substance use variable one month

later were equal in strength ($\Delta\chi^2 = 3.43$, p = .57). Thus, the (non-)significant relationships between substance use and online substance-use-related communication are equal in strength, regardless of the substance use under consideration. Thus, to answer our research question: The relationships between sharing posts about substances on social media and offline substance use are equal in strength, independent of the substance under consideration.

Finally, unrelated to our hypothesis and research question, we also found some cross-over effects between the substances. In particular, we found that marijuana use predicted alcohol use one month later ($\beta = .11$, $SE = .05$, $p < .05$, 95% LLCI/ULCI = .01/.21), and posting alcohol-related content predicted posting marijuana-related content one month later ($\beta = .11$, $SE = .06$, $p = .05$, 95% LLCI/ULCI = -.004/.22). Of the control variables, we found that older individuals consumed more alcohol ($\beta = .10$, $SE = .04$, $p < .05$, 95% LLCI/ULCI = .03/.19), whereas younger individuals were more likely to post about marijuana ($\beta = -.20$, $SE = .06$, $p < .01$, 95% LLCI/ULCI = -.32/-.06), and males consumed more alcohol ($\beta = .11$, $SE = .05$, $p < .05$, 95% LLCI/ULCI = .01/.19) and marijuana ($\beta = .11$, $SE = .05$, $p < .05$, 95% LLCI/ULCI = .02/.15). No other longitudinal relationships were significant, except for the auto-regressive relationships (see Figure 1 and Appendix A).

Discussion

Over the past decade, it has repeatedly been demonstrated that sharing alcohol-related content on social media is associated with greater levels of alcohol consumption (D'Angelo et al., 2014; Geber et al., 2021; Geusens & Beullens, 2017b, 2021a; Litt et al., 2018). This study directly adds to the literature by testing whether the associations between sharing about substance use on social media and offline substance use differs for alcohol, tobacco, and marijuana. Building on the results of our cross-lagged panel model with one-month time lags, we can draw at least three major conclusions about the nature of substance use-related social media self-effects.

First, we did not observe any media effects, only media selection processes. In particular, we found that sharing substance use references was predicted by substance use one month earlier, but not vice versa. This means that individuals are more likely to share posts about substance use on social media if they used this substance more frequently the month before. Our results give weight to the argument that online substance use references may reflect offline behaviors (e.g., Geusens & Beullens, 2017a), but go against the multitude of studies that found sharing substance use references on social media predicts later substance use (e.g., Clendennen et al., 2020; D'Angelo et al., 2014; Erevik et al., 2017; Geber et al., 2021; George et al., 2021; Geusens & Beullens, 2017b; Moreno et al., 2018). Recently, Geusens and team argued that what the literature has been calling 'social media effects', may in actuality reflect group differences, with some young people drinking more alcohol and sharing more about this alcohol consumption without sharing behavior predicting more use (Geusens et al., 2022; Geusens & Beullens, 2021b). In other words, there may be a group of young people who share more about their substance use on social media than their peers, and who also use substances more heavily than their peers, but while the two behaviors may be related, there is no causal relationship between the two. Our results seemingly support this conclusion.

An important reason why we believe we did not find the expected self-effects ties into our second conclusion: the importance of figuring out the most appropriate time lags. This relates to the question first asked by Geusens and Beullens (2021b) and reiterated by Geber et al. (2021): How long should our time lags be when studying substance use-related social media self-effects? Although the one-year time lag seems to be standard when testing substance use-related social media effects (e.g., Clendennen et al., 2020; Erevik et al., 2017; George et al., 2021; Moreno et al., 2018), Geusens and Beullens (2021b) argued that one-year time lags may be too long to capture substance use-related social media self-effects, so Geber et al. (2021) directly built on this to test four-month time lags. In contrast to our findings, they did find the

expected media effect and media selection processes, whereby sharing alcohol-related content predicted drinking behavior four months later, and vice versa (Geber et al., 2021). Perhaps our one-month time lag was too short to capture the expected substance-use-related self-effects, especially for our younger sample who have less access to and opportunities for substance use than previously-studied off-age college samples. Rather the proposed process in self-effects research by which substance-use posts affect how youth view themselves (as substance-using individuals), thus impacting their behavior may instead develop over slightly longer time frames. This would also be an argument to study substance-use-related cognitions in addition to behavior in future studies as there is strong support in the literature indicating that cognitions concerning substance use are significantly related to one's own substance use (Gerrard et al., 2008; Litt & Lewis, 2016), and as such, are important to include when predicting substance use among adolescents and emerging adults.

Clearly, more longitudinal research using different time lags is needed to fully capture the role social media can play in young people's substance use and to delineate a more specific time-frame in which these effects might be expected to operate. This is especially true since our results also demonstrate the importance of using longitudinal studies to test hypotheses, and to be cautious when interpreting cross-sectional data. Whereas we found no cross-lagged effects of sharing substance use references on offline substance use, we did find significant associations between substance use and substance-use related social media posting at each time point. This shows that cross-sectional studies may erroneously claim the positive associations between substance use-related social media communication and offline substance use to be media *effects*.

One interesting method that would provide more insight in both how these effects develop over time and in the closer temporality within lags, are measurement burst designs (Stawski et al., 2015). Measurement burst designs combine intensive repeated measure designs

(e.g., daily diaries) with more traditional longitudinal panel designs, and allow for 'nonequally-spaced assessments', or to combine different time lags within one study (Stawski et al., 2015). It would be especially interesting to combine this methodology with more objective measurements of substance use-related sharing behaviors, such as social media data logging or content analyses. In this study, we relied on self-reports, but recent research has demonstrated that individuals have a tendency to overestimate how often they share alcohol posts on social media (Geusens & Beullens, 2021c) and studies relying on self-report data only may overestimate the true strength of the association between sharing alcohol-related content on social media and alcohol consumption (Geusens & Beullens, 2021a). Thus, combining innovative longitudinal designs, such as measurement burst designs, with objective social media measurements, such as content analyses, would significantly improve our understanding of how and when substance use-related communication on social media can predict offline substance use.

Third, it seems that although we did not find any media effects, the strength of the associations between substance use-related social media posting and offline substance use is equal for the three substances we studied (i.e., alcohol, tobacco, and marijuana). Thus, regardless of the social acceptability of the substance under consideration, it appears that conclusions from one area of research (e.g., alcohol-related social media self-effects) may be generalizable to other substance use-related social media self-effects research. Considering that remarkably little research has been conducted on tobacco- and marijuana-related social media self-effects, especially compared to alcohol-related social media self-effects, this potential generalizability offers a breadth of new insights to these fields. However, it should be noted that although using tobacco, alcohol and marijuana were similarly related to subsequent sharing about these substances, the relationship between using tobacco and sharing tobacco-related posts on social media was not significant. This is likely due to how few people in our sample

were actually using and communicating about tobacco. Based on our results, we expect that if this study was replicated with a larger sample including more individuals who use tobacco, we would find the same positive association between using tobacco and sharing tobacco-related posts on social media one month later, as we observed for alcohol and marijuana.

Clinical Implications

There are several potential ways in which these findings could contribute to improving substance use screening and/or prevention and intervention efforts among adolescents and emerging adults. Given that our findings suggest that sharing alcohol, marijuana, and tobacco content on social media reflects more frequent use, it is possible that one's social media displays or posts can be used to help identify individual who may be at risk for using alcohol and marijuana. For example, most social media platforms allow for targeted messaging or advertising based on searches, posts, and keywords so targeted intervention messages or links to additional prevention strategies could be disseminated based on one's own social media activity. Thus, it is possible that clinicians, researchers, schools, and other community organizations could send alcohol or marijuana prevention programs to individuals based on which substance or substances they shared on social media. Given that no single intervention is likely to sufficiently reduce adolescent and emerging adult substance use, it has been suggested that a "mix of strategies is best" (NIAAA, 2019). Thus, identifying individuals at risk based on their social media behavior and using this identification as a means to deliver intervention content via these platforms is one possible way to add to the toolbox of efficacious strategies for reducing substance use among adolescents and emerging adults.

Limitations

As with all research, this study has several limitations. First, as already discussed in more detail above, this study relied on self-report data. Although self-report data on substance use seems to be relatively accurate (Del Boca & Darkes, 2003), it has been argued that self-

report data on substance use-related communication on social media may not be as reliable, at least for alcohol (Geusens & Beullens, 2021c). Future studies would benefit from combining self-report data on substance use with more objective data on substance use-related social media sharing, such as content analyses. Furthermore, we used single-item measures for all of our main variables. However, singe-item measures are not necessarily worse than multiple-item measures when they measure concrete constructs (Bergkvist, 2015), such as substance use or social media use. In addition, there are currently no validated scales to measure substance-use-related communication on social media. This is a limitation for the field in general, and we hope that as the field further develops, validated measures will be developed as well.

Furthermore, there may also be some overlap between the baseline and follow-up measurement of substance use-related posting, because we did not specify a timeframe for these questions. Future studies would benefit from setting a clear time frame that is aligned with the substance use time frame, to better disentangle the temporality of the effects. Although the sample size was in line with other studies on substance-use-related social media effects (e.g., Geusens & Beullens, 2021c; Moreno et al., 2021), it was potentially too small to detect small effect sizes. It is possible that our sample size has led to type II error or failure to detect significant effects, such as the self-effects under consideration (Columb & Atkinson, 2016). A replication of our study in a larger sample is recommended. Relatedly, we originally aimed to compare effect sizes for adolescents and emerging adults, but the sample was not large enough to meaningfully compare these groups. Therefore, when our study is replicated in a larger sample, we suggest recruiting enough adolescents and emerging adults so that analyses can be split by age to examine potentially differential processes.

This study is a secondary analysis of an experimental study (Litt et al., under review). The study was not originally designed with these hypotheses and research questions in mind. Nevertheless, the hypotheses and research questions were developed by the first author before

gaining access to the dataset, and the authors were careful not to 'HARK' or hypothesize after the results were known (Kerr, 1998). Considering that this is secondary data analysis, we could not control for other potentially relevant variables, such as social norms for all substances (only alcohol norms were measured in the larger study), parental and peers' substance use, personality traits, or academic success, because these were not measured in the original study. Follow-up research would benefit from measuring more control variables to test whether the results uphold. Furthermore, the original study focused on *alcohol*-related social media effects. As such, the original eligibility criteria focused on alcohol use, and not on the other substances. Nevertheless, not only participants who drink alcohol, but also those who use tobacco and marijuana seem to be overrepresented in our study compared to the general population. Substance use prevalence reports show that in 2018, 27.9% of 12th-graders in Washington State used alcohol in the past month, 8% of them smoked tobacco, and 26.2% used marijuana (Washington State Health Care Authority et al., 2019).

Finally, while we were interested in finding out whether substance use-related social media effects were different depending on the social acceptability of the substance use under consideration, we did not actually measure social acceptability or other risk-cognitions related to the three substances. Building on the literature, we expected that alcohol use is more socially acceptable than tobacco and marijuana use for our sample, but this was not formally tested. Relatedly, the concept of 'social acceptability' as well as other risk cognitions such as descriptive norms, attitudes, and risk perceptions are likely dependent on the social and cultural context of the sample under consideration, and is expected to be different for other samples (e.g., countries where alcohol is illegal, countries with a lower legal drinking age, or states or countries were marijuana use is still illegal). More cross-cultural research comparing samples with different legal and cultural substance use norms would be beneficial.

Conclusion

There is little understanding of the different roles social media may play in substance use of differing social acceptability, particularly alcohol, tobacco, and marijuana use. Using a cross-lagged panel study with a one-month time lag among a sample of 282 15-20-year-olds in the United States, we observed no self-effects of sharing substance use references on later substance use, but we did observe selection effects, in that those who consumed more alcohol and marijuana, were more likely to post about this on social media one month later. Moreover, we found no differences in the strength of these effects when comparing alcohol, tobacco, and marijuana. This suggests that these selection effects are similar for the three substances under consideration.

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Table 1.

Substance Use Patterns.

	Alcohol (baseline)	Alcohol (1-month follow up)	Tobacco (baseline)	Tobacco (1-month follow up)	Marijuana (baseline)	Marijuana (1-month follow up)
Did not use in the past month	10.1%	16.4%	75.2%	76.5%	50.0%	46.0%
Once	14.1%	12.5%	9.8%	9.7%	13.4%	15.8%
Twice	15.4%	16.4%	2.9%	2.5%	9.2%	10.4%
Three times	14.7%	14.3%	4.6%	2.2%	9.2%	6.5%
Once a week	14.1%	12.9%	2.3%	3.2%	6.5%	7.9%
Twice a week	15.0%	12.9%	1.6%	2.5%	3.6%	5.4%
Three times a week	8.5%	9.6%	1.3%	1.1%	2.6%	2.5%
Four times a week	6.9%	2.5%	1.3%	0.7%	1.3%	1.8%
Five times a week	0.7%	1.1%	0.7%	0.7%	2.0%	0.7%
Six times a week	0.3%	1.1%	0.0%	0.0%	0.7%	0.4%
Every day	0.3%	0.4%	0.3%	0.7%	1.0%	1.1%
More than once per day	0.0%	0%	0.0%	0.0%	0.7%	1.4%
M	3.31	3.01	0.72	0.71	1.67	1.78
SD	2.14	2.21	1.66	1.72	2.38	2.45

Table 2

Zero-Order Correlation Table Depicting Bivariate Correlations Between the Variables in our Analyses.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. Alcohol use baseline															
2. Alcohol use follow-up	.70***														
3. Tobacco use baseline	.27***	.33***													
4. Tobacco use follow-up	.30***	.32***	.82***												
5. Marijuana use baseline	.24***	.27***	.33***	.32***											
6. Marijuana use follow-up	.25***	.35***	.32***	.35***	.83***										
7. Alcohol posting baseline	.28***	.24***	.22***	.14*	.17**	.19***									
8. Alcohol posting follow-up	.33***	.33***	.26***	.16*	.19**	.17**	.68***								
9. Tobacco posting baseline	.13*	.15*	.34***	.29***	.17**	.17**	.15**	.19**							

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GENERALIZABILITY SUBSTANCE USE SOCIAL MEDIA EFFECTS

|	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10. Tobacco posting follow-up	.14*	.22***	.35***	.43***	.21***	.20***	.11	.21***	.50***						
11. Marijuana posting baseline	.12*	.13*	.18***	.20***	.54***	.48***	.31***	.34***	.23***	.21***					
12. Marijuana posting follow-up	.05	.10	.17**	.11	.49***	.46***	.31***	.36***	.13*	.18**	.63***				
13. Age	.29***	.30***	.06	.08	.003	.04	.12*	-.003	.-03	-.03	-.09	-.22***			
14. Sex at birth	.13*	.21***	.07	.11	-.01	.09	-.08	-.06	-.002	.04	-.05	-.10	.13*		
15. Control vs abstaining condition[a]	-.03	-.02	.08	.06	.09	.08	-.02	-.08	.03	.05	.04	.01	-.04	-.01	
16. Control vs abstaining/drinking condition[a]	-.003	-.01	-.09	-.05	-.10	-.09	.01	-.01	-.03	.03	-.06	.01	.01	.001	-.51***
Range	0-10	0-10	0-11	0-10	0-10	0-11	0-1	0-1	0-1	0-1	0-1	0-1	15-20	0-1	0-1

Notes: Substance use was measured as frequency of use during the past month (0-11) and social media posting was measured as yes/no (1/0).

[a] The original study was designed as an experiment with three conditions. To control for this design, the experimental conditions were entered as two dummy variables: abstaining versus control and abstaining/drinking versus control.

* $p < .05$, ** $p < .01$, *** $p < .001$

Figure 1. Standardized Results of the Cross-Lagged Panel Model.
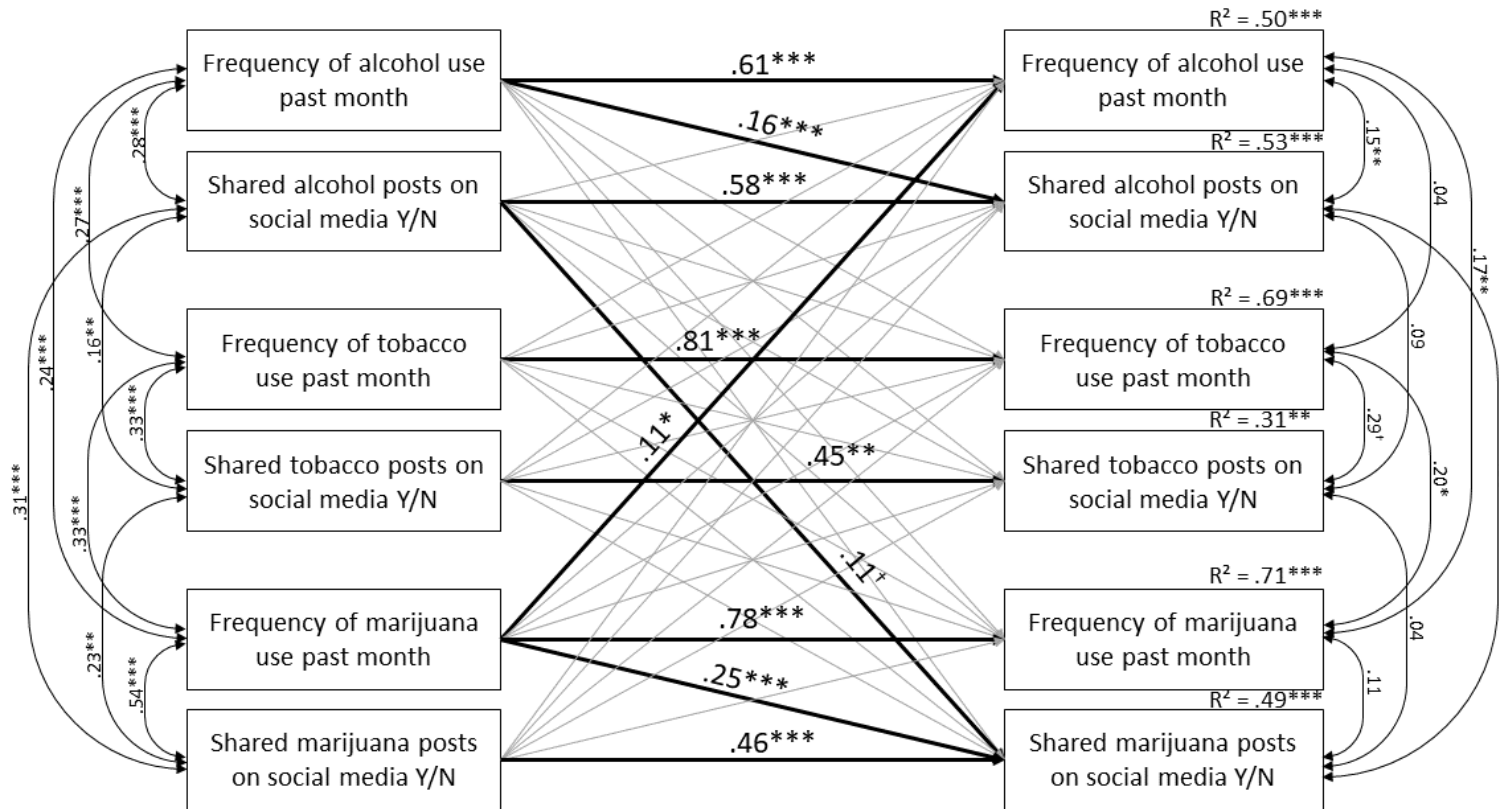
Notes. Model fit: $\chi^2 = 51.57$, df = 24, $p < .001$, RMSEA = .06, CFI = .98, TLI = .93, SRMR = .04

Non-significant associations are greyed-out. Age, birth sex and the experimental conditions are added as control variables. Full SEM results can be found in appendix A.

† $p = .05$ * $p < .05$, ** $p < .01$, *** $p < .001$.