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Associations between digital technology and substance use among U.S. adolescents: Results from the 2018 Monitoring the Future Survey

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Abstract

Objective—Social media and other digital technology use facilitate connection among adolescents, but also may reinforce norms and substance-related content from peers and advertisers. We use nationally representative data to examine the association between digital technology and past 30-day use of alcohol, cannabis, and vaping.

Methods—Data were drawn from the 2018 Monitoring the Future survey of US adolescents (N=44,482). Poisson regressions estimated the association between hours/day of technology use and past 30-day use of alcohol, cannabis, and vaping adjusting for grade, sociodemographics, and other past-year drug use.

Results—Across grades, mean hours of social media/day was 3.06 (standard deviation=2.90), past 30-day alcohol, cannabis, flavor vaping, cannabis vaping, and nicotine vaping were 15.7%, 12.6%, 10.6%, 4.9%, and 11.2%, respectively. Digital technology use that required interaction with others was associated with increased risk of past 30-day drinking, cannabis use, and vaping. For example, social media 3+ hours/day was associated with past 30-day drinking (adjusted relative risk [aRR]: 1.99, 95% CI: 1.65, 2.41). The magnitude of association was consistent across texting, phone calls, and video chatting, which were all more strongly associated with substance use than with activities that do not require interaction such as gaming and watching videos.

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All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Conflict of Interest
None

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Conclusion—Digital technology that facilitates interaction among adolescents, such as texting and social media, is associated with past substance use. Magnitudes of association are consistent across substances, supporting the hypothesis that networks of adolescents are social drivers of substance use, rather than the technology itself.

Keywords

adolescents; youth; social media; marijuana; alcohol; vaping

1. Introduction

Smart phones and digital technology are ubiquitous among adolescents and facilitate new ways for adolescents to connect. For example, >90% of teens reported multi-daily engagement with social media (e.g. Instagram, Facebook, Snapchat) (Pew Research Center, 2018). While digital technology has potential benefits for social connection (Gross, 2009; Lee, 2009; Pew Research Center, 2018), they also provide a new vector to introduce and reinforce social norms around substance use (Cabrera-Nguyen et al., 2016; Frost and Rickwood, 2017; Miller et al., 2014), as well as expose adolescents to substance-related advertising (Camenga et al., 2018; Jernigan et al., 2017; Krauss et al., 2017; Pokhrel et al., 2018). Historically, manufacturers of addictive products such as alcohol and nicotine have targeted advertising to adolescents in an effort to gain a new market share (Chester et al., 2010; King III and Siegel, 1999; Pucci and Siegel, 1999). While regulation has reduced advertisers' ability to market to adolescents using traditional media (magazines, TV, etc.), particularly alcohol (Anderson et al., 2009; Jernigan, 2011), new media types may offer other ways to display products to a young market.

Available evidence indicates that exposure to substance-related content, both from peers and advertisers, is common when engaging with digital media, and that involvement with wider social networks and friends engaged with substance-related content is associated with higher substance use (Cabrera-Nguyen et al., 2016; Frost and Rickwood, 2017; Hoffman et al., 2014; Huang et al., 2014). While existing research has predominately focused on alcohol, cannabis content is rapidly expanding given shifting legal markets, and social media depictions of use and users, as well as advertising, are becoming more frequent. Indeed, cannabis advertising is more common on social media that traditional media (Krauss et al., 2017), and cannabis posts by young people on social media are not only more frequent than older adults, but also largely positive in nature (Park and Holody, 2018) and associated with higher levels of cannabis use (Cabrera-Nguyen et al., 2016).

In addition to alcohol and cannabis, vaping and e-cigarette use have increased dramatically among youth in since 2016 (Miech et al., 2019), and social media advertising and peer content has followed. In addition to high levels of e-cigarette advertising in traditional sources such as stores (Margolis et al., 2018), exposure to e-cigarette content on social media is associated with future e-cigarette use (Camenga et al., 2018; Pokhrel et al., 2018), with variation based on social media site.

Many ofthe aforementioned studies focus on specific subsets of the population and, therefore, the total population Journal association between exposure to digital media and risk

of alcohol, cannabis and e-cigarette use remains inadequately identified. Furthermore, the landscape of both digital technology use(Pew Research Center, 2018)as well as substance use (Miechetal., 2019)is rapidly changing among youth. Therefore, evaluation of the relationship between digital technology and substance use requires up-to-date data. We use 2018 Monitoring the Future (MTF) data to examine the association between adolescent exposure to traditional and newer forms of media and substance use, namely alcohol (past 2-week binge drinking and past 30-day use), cannabis(past 30-day use), and vaping(past 30-day use). Monitoring the Future is the only national study containing stream-lined, well-replicated measures of digital media engagement and substance use among US school-attending adolescents in 8th, 10th, and 12th grade, thus providing a large sample size and allowing for nationally representative inferences.

2. Methods

2.1. Sample

MTF includes annually administered cross-sectional surveys of 8th, 10th, and 12th grade students in the contiguous US. The survey is conducted at approximately 400 U.S. public and private high schools selected using a multi-stage random sampling design. Selected schools are invited to participate in MTF for 2 years, and schools that decline to participate are replaced with schools that have similar size, geographic location, and urbanicity. While the questionnaire is administered annually, the present study focuses on 2018 as this was the first year that hours per day of media use was queried. The 2018 survey had high school high participation rates: 89%, 86%, and 81% for 8th, 10th, and 12th grade, respectively (Miech et al., 2019). Almost all nonresponse was due to absenteeism; less than 1% of Pre-proof students refused to participate. A detailed description of MTF design and procedures are provided elsewhere (Bachman et al., 2015; Miech et al., 2019). We use sampling weights provided by MTF in all calculations to take into account selection probabilities and differences in sample sizes between schools.

MTF uses a self-administered questionnaire comprising a core form given to all participants that includes assessment of substance use and other key modules, and secondary forms randomly assigned to each participant that contain additional questions; we focus on students who received a form that included questions regarding entertainment, social media, and cell phone use, as well as substance use behaviors. These questions overlapped on 1–2 of 6 forms among 12th grade students (except vaping questions, which did not overlap with media questions), and all forms among 8th and 10th grade students. Form was included as a covariate in all analyses. The maximum sample size for this analysis was 44,482 (14,836 8th graders, 15,144 10th graders, and 14,502 12th graders). Missing data due to nonresponse ranged from 2.42% for the question pertaining to hours per day gaming to 8.80% for the question pertaining to past 30-day drinking.

2.2. Measures

2.2.1. Entertainment, Social Media, and Cell Phone Use—Students were asked “About how many hours on an average day do you spend: a. playing games on a computer, TV, phone, or other electronic device? b. texting? c. talking on the phone? d.

on social networking Web sites like Facebook, Twitter, Instagram, etc.? e. video chatting (Skype, etc.)?" In addition, students were asked "How many hours do you estimate you watch Pre-provideo, TV,ormoviesonanelectronic device (such as a TV, computer, tablet or smartphone)? a. on an average weekday? b. on an average weekend day?" Scales for both sets of questions were: none, less than 1 hour, 1–2 hours, 3–4 hours, 5–6 hours, 7–8 hours, and 9 hours or more. For our study, we combine higher groups to "3 or more hours". Students were additionally queried about hours spent shopping online and emailing; we did not include those analyses in this paper.

2.2.2. Substance Use—Frequency of substance use in the past 30 days was assessed as: 0, 1–2, 35,6–9,10–19,0–39, and 40+ occasions. We assessed any use (>=1 occasion) for alcohol, cannabis, flavor vaping, cannabis vaping, and nicotine vaping, as well as occasions of use of each as a Poisson distributed outcome. Number of occasions of consuming 5+ drinks (binge drinking) in the past two weeks was also assessed. For 12th graders, questions pertaining to vaping were asked on a different form than the entertainment, social media, and cell phone use questions, so we assessed relationships for 8th and 10th grade students only.

2.2.3 Other Behavioral and Parental Covariates—Two items measured *sensation-seeking*: "I get a real kick out of doing things that are a little dangerous" and "I like to test myself every now and then by doing something a little risky". Three measures of internalizing symptoms are analyzed (low self-esteem, high self-derogation, and depressive affect). Four items measured *self-esteem*: "I take a positive attitude toward myself… I feel I am a person of worth, on an equal plane with others… I am able to do things as well as most other people… On the whole, I'm satisfied with myself." Four items measured *self-derogation*: "I feel I do not have much to be proud of… Sometimes I think that I am no good at all… I feel that I cant do anything right… I feel that my life is not very useful." Four items measured *depressive affect*: "Life often seems meaningless… The future often seems hopeless… I enjoy life as much as anyone… It feels good to be alive." Response options for these statements were on a Likert scale (disagree, mostly disagree, neither, mostly agree, agree). Similarly, students were asked how often(never,rarely, sometimes, most times, always) these statements related to *parental monitoring* occurred: "My parents know where I am after school… When I go out at night, my parents know whom I am with… When I go out at night, my parents know where I am." Items within each measure were averaged to create one item. Questions for the aforementioned measures (sensation-seeking, parental monitoring, and internalizing symptoms) were included on different forms of the survey and, thus, were asked of different participants. Therefore, we included each measure in separate analyses. Parental monitoring questions were also on a different form than vaping questions, precluding analyses of associations between these variables.

2.2.4. Sociodemographics—We included self-reported sociodemographic variables as control variables (percentages reported are for the entire sample): grade (8th grade, 10th grade, or 12th grade), sex, race/ethnicity (White, Black, Hispanic, multiple races, other) most recent grade point average (GPA) ('B' average or higher, or 'less than B' average) and

highest level of parental education received (some high school, high school/some college, or college or higher).

2.3. Statistical Analysis

First, descriptive analyses graphically examined the association of number of hours spent per day on entertainment, social media, and cell phone use and substance use. For brevity, histograms for 10th grade students are provided in the main results, and histograms for 8th and 12th grade students are included in Supplemental Figures 1 and 2, respectively.

Second, we estimated Poisson regressions (Zou, 2004) of associations between hours/day on entertainment, social media, and cell phone use and each substance use outcome, adjusting for the sociodemographic variables (i.e. grade, race/ethnicity, most recent GPA, and highest level of parental education received), past-year substance Pre-puse,and assigned instrument form. We also performed sensitivity analyses in which we included hours/day using digital technology in the Poisson regression as a continuous variable to test whether using hours/day as a categorical variable might lead to loss of power, information loss, or removal of confounding control (Van Walraven and Hart, 2008). We then included measures of sensation seeking, parental monitoring, or internalizing symptoms in our Poisson regressions to determine whether any observed associations between digital technology and past substance use were spurious. Lastly, we estimated Poisson regressions of associations between hours/day on entertainment, social media, and cell phone use and occasions of substance use among users, adjusting for the aforementioned covariates.

We conducted data management and analysis in SAS, version 9.4. (SAS Institute, Inc., Cary, North Carolina) (SAS Institute Inc., 2014). Graphs were generated in ggplot2 (Wickham and Chang, 2014) in R software (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

Table 1 provides participant sociodemographic data. A majority of a sample comprised 8th (42.6%) and 10th graders (43.5%). The sample was balanced in terms of sex: 50.8% female and 49.2% male. A majority of participants self-identified as white (46.0%) and came from families where the maximum parental education was college or higher (55.4%). Spearman's correlations between digital technology use variables were very weak to moderate, ranging from 0.08 (coefficient between hours spent video chatting and hours spent watching videos on the weekend) to 0.54 (coefficient between hours spent texting and hours spent social networking).

Figure 1 shows the prevalence of substance use by hours/day spent on social media, digital communication, and entertainment among 10th grade students (results for 8th and 12th grade students are Supplemental Figures 1 and 2, respectively). In general, there were positive and consistent relationships between use of each substance with use of technologies that require interaction: social media, texting, talking, and to a lesser extent, video chatting. For example, the prevalence of past 30-day drinking was 7.5% among students who report no hours of social media use, and 23.0% among students who report 3+ hours of social media use. Results were similar for texting; the prevalence of past 30-day drinking was

8.4% among students who report no hours texting/day, and 23.0% among students who report 3+ hours of texting/day. In contrast, a limited signal emerges for technologies that do not require interaction: gaming and watching videos on weekend days. For example, the prevalence of alcohol use among students who report no gaming hours was 20.8%, similar to the prevalence among students who report 3+ hours of gaming (18.7%). The exception to the pattern of substance use trends by whether the activity required interaction was for watching videos on weekdays, which was associated with most substances examined. Results were similar in direction for 8th and 12th grade students (see Supplemental Figures 1 and 2).

Table 2 shows Poisson regressions of the associations between social media and digital communication with past substance use, adjusting for grade, sex, race, GPA, highest level of parental education, past-year substance use, and assigned instrument form. Results confirmed that digital technology use was associated with past substance use, across many forms of technology including social media, texting, talking, and video chatting. Any amount of social networking per day significantly increased students' risk of past 30-day drinking. Students who used social media 3+ hours per day had 1.99 (95% CI: 1.65, 2.41) times higher risk of past 30-day drinking. Any amount of texting, talking on the phone, or video chatting per day significantly also increased students' risk of past 30-day drinking, adjusting for the aforementioned covariates. Any amount of talking on the phone or video chatting, compared with none, was associated with past 2-week binge drinking and past 30-day cannabis use, adjusting for the aforementioned covariates. Lastly, any amount of talking on the phone, compared with none, was associated with past 30-day flavor, cannabis, and nicotine vaping. In contrast, Table 2 shows associations for activities that do not require interaction with others and past substance use were of substantially lower magnitude. Poisson regressions run without adjusting for past-year substance use provided similar associations (see Supplemental Table 1), but results were less attenuated.

Sensitivity analyses in which hours/day of digital technology use were included as a continuous variable in the Poisson regressions yielded similar results, with some exceptions (Supplemental Table 2). Associations between talking on the phone and past 30-day cannabis and flavor vaping became non-significant. In addition, watching videos on weekends emerged as inversely associated with past 30-day nicotine vaping. For every one hour increase in watching videos on the weekend, students had 0.95 (95% CI: 0.93, 0.98) lower adjusted risk of past 30-day cannabis vaping than those who did not watch videos on weekends. The inclusion of other behavioral and parental covariates also yielded similar results, with some exceptions. After adjusting for sensation seeking, the association between 3+ hours of video chatting and past 2-week binge drinking was reduced in magnitude, and the association between <1 hour of video chatting and past 30-day cannabis use was reduced in magnitude Pre-proof (Supplemental Table 3). Similarly, associations between talking on the phone and video chatting and past substance use became more attenuated after controlling for parental monitoring (Supplemental Table 4). Lastly, after adjusting for internalizing symptoms, the association between <1 hour/day of talking on the phone and video chatting and past 30-day cannabis use was reduced in magnitude (Supplemental Table 5). However, any amount of video chatting was positively associated with past 30-day flavor vaping (Supplemental Table 5).

Table 3 shows Poisson regressions indicating that among past substance users, increases in hours spent social networking and communicating digitally were generally associated with increased occasions of substance use, except for past 30-day cannabis use and flavor-vaping across all forms of digital communication. For example, compared to students who don't use social media, the expected log count for those who use social media for 3+ hours increased by 0.294 (95% CI: 0.087, 0.501) for past 2-week binge drinking and 0.145 (95% CI: 0.052, 0.239) for past 30-day drinking. Compared to students who don't talk on the phone, the expected log count for those who talk for 3+ hours increased by 0.254 (95% CI: 0.171, 0.337) for past 30-day nicotine vaping. In contrast, the Poisson models indicated that among past substance users, increased hours spent gaming and watching videos were associated with decreased occasions of substance use across substances, except for past 30-day cannabis use by hours spent gaming (Table 3). Poisson regressions run without adjusting for past substance use provided similar associations (see Supplemental Table 6), but results were less attenuated.

4. Discussion

This study is the first to estimate associations between digital technology and substance use using nationally representative data among the current cohort of US adolescents. We find that digital technology, including social media,isassociated with past substance use in adolescents. However, this association is present across many forms of digital communication, including texting, talking on the phone, and video chatting. In contrast, we generally did not observe consistent associations between gaming or watching videos and past substance use. In fact, we found some instances in which watching videos was associated with lower odds of past substance use. Sensitivity analyses in which hours/day of digital technology use were included as a continuous variable and in which behavioral and parental covariates were included generally yielded similar results. These differences support the hypothesis that social interactions drive substance use among adolescents, which is illustrated in how adolescents now more commonly communicate. Social networking, texting, and talking by default requires interaction with others, and digital communication is often used to directly interact with another individual. However, gaming and watching videos, although sometimes social activities, can easily be done solitarily, especially with the rise of single-player video games and streaming services such as Hulu and Netflix that make at-home movie watching easily accessible and inexpensive (Leonhardt, 2019). In summary, while social media may be exposing adolescents to advertising content and peer norms around addictive products, these results suggest that patterns of use are more consistent with social interactions in general, rather than social media in particular being a risk factor for substance use.

The role of peer interactions in substance use has been extensively documented for decades. Individuals who have wider peer groups are more likely to be exposed to peers that use substances (Bahr et al., 2005; Kandel, 1985), and to have opportunities to use (Crum et al., 1996; Lloyd and Anthony, 2003). As new ways for adolescents to engage with each other become available, increased frequency of digital communication may become a proxy for adolescents who are more socially engaged in general, thus, some part of the associations with peer-engagement and substance use may be reproduced via digital

communication. We hypothesize that these adolescents are more social online and offline, increasing their opportunity risk and might enjoy spending unsupervised time with friends. Existing literature indicates that adolescents who use technologies that promote interaction, such as social media, are more likely to use substances (Brunborg et al., 2017; Brunborg and Andreas, 2019; Gommans et al., 2014; Gutierrez and Cooper, 2016; Ohannessian et al., 2017), underscoring that the results presented here are consistent with the broader literature.

While the associations observed here are consistent with a social interaction mechanism, it is worth underscoring that new modes of technology have the potential to expose adolescents to advertising aimed at increasing substance use (Anderson et al., 2009). Vaping is particularly concerning; recent data indicate a dramatic increase in adolescent use, especially of JUUL products (Fadus et al., 2019). JUUL accounted for about 40% of e-cigarette retail market shares for last quarter of 2017 (Huang et al., 2019) and often targets youth in their advertisements (Fadus et al., 2019). and adolescents who were exposed to advertising of e-cigarettes such as JUUL were more likely to experiment with e-cigarette use (Chen-Sankey et al., 2019). Additionally, recent evidence indicates that young adult cannabis users seek cannabis advertisements on social media, and it is now a larger source of cannabis advertising than traditional media (such as print, radio, and television) Pre-proof(Kraussetal., 2017).Indeed,the proportion of substance-related advertisements on social media platforms is alarming. An analysis of publicly available Instagram posts with cannabis-related hashtags found that 43% of posts had explicit content about cannabis use, of which 9% contained cannabis-related advertisement (Cavazos-Rehg et al., 2016).

Wider social networks, as indicated by more time on social media, texting, talking, and other forms of engagement also may increase substance use through peer modeling of substance-related behavior, both offline and online. For instance, exposure to pro-alcohol posts from friends on Twitter was associated with higher odds of current heavy episodic drinking compared to no exposure (Cabrera-Nguyen et al., 2016). Having more Facebook friends also predicted greater alcohol consumption (Frost and Rickwood, 2017). Interestingly, having more friends also predicted posting alcohol-related content on Facebook for the first time among those commencing college (Frost and Rickwood, 2017), thereby increasing one's Facebook friends' exposure to pro-alcohol content and perpetuating the cycle of observing posts and drinking. Similar to trends in alcohol use, exposure to social media content from peers is also linked to higher levels of cannabis use. In general, adolescents who report having friends who used cannabis had higher odds of ever using cannabis themselves (Roditis et al., 2016). The odds of current cannabis use were almost three times higher for those exposed to pro-cannabis posts from friends on Twitter compared to those with no exposure (Cabrera-Nguyen et al., 2016).

Although these aforementioned studies imply that youth exposure to advertisement and pro-substance content are associated with increased substance use, studies on restricting exposure and resulting substance use reduction have been Pre-mixed. A prospective observational study in Germany determined that parental restriction from watching movies rated for those 16 years and over decreased substance use risk among adolescents (Hanewinkel et al., 2008). However, a 2014 systematic literature review concluded that there is a lack of robust evidence to support or refute the impact of alcohol advertising restrictions

on subsequent substance use (Siegfried et al., 2014). The lack of congruence among these studies indicates a need for more rigorous studies using nationally representative data containing indicators that specifically identify content exposure.

Our study has several limitations. Although our results support the hypothesis that adolescent social networks are drivers of substance use, rather than digital technology itself, it is possible that youth who engage in social interactions with others using digital media reflect different sub-popultions of youth, or different types of digital technology may expose youth to different substance-related content. Therefore, these associations are also not intended to be interpreted as causal estimates given that data are cross-sectional, and there may be uncontrolled confounding. The data are also self-reported and, thus, may be susceptible to recall and reporting bias. Furthermore, the available digital media measures in these data are limited. Since we have no direct measure of exposure to advertising, we use other exposures as a proxy and infer that advertising and pro-substance content from peers are the underlying mechanisms for increased substance use in youth. Although MTF is generalizable to school-attending adolescents, results in this study might not be relevant for non-school attending adolescents and non-US residents. Lastly, we do not have data for 12th graders regarding past vaping use.

Smart phones and digital communication are ubiquitous in adolescents' lives. Assessing newer potential sources of exposure to pro-substance content is a vital part of monitoring the everchanging landscape of adolescent substance use. This study provides evidence that social media, texting, talking on the phone, and video chatting are associated with past substance use in adolescents, suggesting that social interactions drive adolescent substance use, with social networks and digital communication providing a medium for these interactions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- Social media and digital technology exposes youth to substance-related content
- Adolescents who use social media are more likely to use substances
- This relationship is also observed across other forms of digital communication
- More socially connected adolescents are more likely to use substances

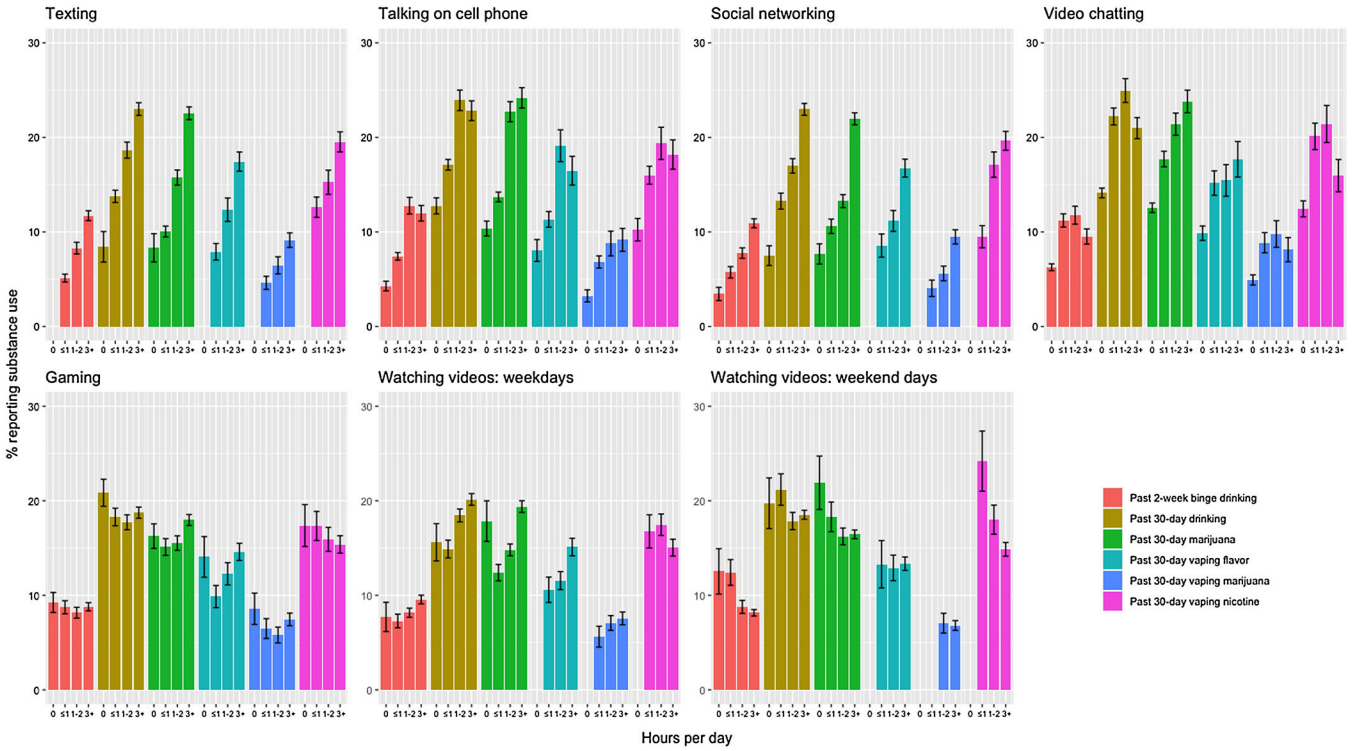

Figure 1.

Histograms of past substance use prevalence by hours spent using digital communication or digital media among 10th graders

Table 1.

Sociodemographic characteristics of 8th, 10th, and 12th grade students in Monitoring the Future Study 2018 (n=32,759)

	Unweighted N	Weighted % (SE)/ Mean (SE)
Age (years)	32.759	15.05 (0.01)
Grade		
8th	14.836	42.62 (0.32)
10th	15.144	43.50 (0.33)
12th	4.823	13.88 (0.23)
Female	16.132	50.78 (0.34)
Race/ethnicity		
White	15.503	46.02 (0.34)
Black	3.940	12.18 (0.23)
Hispanic	9.240	29.80 (0.32)
Multiple	1.774	5.43 (0.15)
Other	2.222	6.57 (0.16)
GPA lower than B	9.501	29.92 (0.31)
Maximum Parental Education		
<High school	3.097	10.76 (0.22)
Finished high school or some college	9.819	33.89 (0.34)
Finished college or graduate school	17.140	55.35 (0.35)
Past-year drinking	10.278	31.51 (0.32)
Past-year cannabis use	7.133	21.31 (0.28)
Past-year use of other drugs	2. 631	8.19 (0.19)

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Table 2.

Poisson regressions of associations between digital technology use and past substance use among 8th, 10th, and 12th graders in 2018[a]

		Past 2-week binge drinking[b]	Past 30-day drinking[b]	Past 30-day cannabis use[c]	Past 30-day flavor vaping[d]	Past 30-day cannabis vaping[c]	Past 30-day nicotine vaping[d]
		N = 23071	N = 23241	N = 23258	N = 6985	N = 7020	N = 6998
Hours spent texting	0	REF	REF	REF	REF	REF	REF
	< 1	1.12(0.74, 1.69)	**1.45 (1.1, 1.9)**	1.32 (0.97, 1.8)	1.13 (0.63, 2.05)	1.41 (0.67, 3)	1.36 (0.77, 2.43)
	1–2	**1.54 (1.02, 2.33)**	**1.82 (1.38, 2.4)**	**1.85 (1.36, 2.52)**	1.71 (0.95, 3.09)	1.95 (0.93, 4.08)	1.62 (0.91, 2.88)
	3+	**1.86 (1.24, 2.8)**	**2.03 (1.54, 2.67)**	**2.17 (1.6, 2.94)**	**2.09 (1.17, 3.71)**	**2.1 (1.03, 4.3)**	**1.81 (1.02, 3.19)**
		N = 22943	N = 23113	N = 23130	N = 6949	N = 6983	N = 6963
Hours spent talking on cell phone	0	REF	REF	REF	REF	REF	REF
	< 1	**1.45 (1.2, 1.77)**	**1.32 (1.17, 1.47)**	**1.15 (1.01, 1.31)**	**1.45 (1.07, 1.97)**	**1.96 (1.25, 3.09)**	**1.27 (1, 1.63)**
	1–2	**1.85 (1.49, 2.28)**	**1.44 (1.27, 1.63)**	**1.49 (1.29, 1.71)**	**2.18 (1.59, 3)**	**2.14 (1.31, 3.51)**	**1.57 (1.2, 2.05)**
	3+	**1.97 (1.58, 2.45)**	**1.59 (1.4, 1.8)**	**1.58 (1.37, 1.83)**	**1.97 (1.42, 2.73)**	**2.28 (1.38, 3.74)**	**1.42 (1.08, 1.87)**
		N = 22911	N = 23082	N = 23100	N = 6933	N = 6968	N = 6946
Hours spent social networking	0	REF	REF	REF	REF	REF	REF
	< 1	1.33 (0.96, 1.83)	**1.42 (1.16, 1.74)**	1.12(0.87, 1.43)	1.47 (0.89, 2.44)	1.1 (0.53, 2.28)	1.3 (0.81, 2.1)
	1–2	**1.45 (1.08, 1.96)**	**1.67 (1.38, 2.02)**	**1.55 (1.23, 1.96)**	**1.66 (1.02, 2.69)**	1.47 (0.76, 2.85)	**1.75 (1.11, 2.75)**
	3+	**1.85 (1.38, 2.49)**	**1.99 (1.65, 2.41)**	**1.94 (1.55, 2.44)**	**2.48 (1.56, 3.96)**	1.85 (0.98, 3.49)	**2.06 (1.31, 3.21)**
		N = 22980	N = 23150	N = 23167	N = 6967	N = 7003	N = 6980
Hours spent video chatting	0	REF	REF	REF	REF	REF	REF
	< 1	**1.44 (1.26, 1.64)**	**1.35 (1.25, 1.47)**	**1.15 (1.05, 1.27)**	1.26(1.05, 1.52)	**1.47 (1.11, 1.95)**	**1.26 (1.07, 1.49)**
	1–2	**1.38 (1.18, 1.62)**	**1.34 (1.22, 1.47)**	**1.37 (1.22, 1.54)**	1.25 (0.99, 1.59)	**1.47 (1.04, 2.07)**	**1.37 (1.12, 1.68)**
	3+	**1.28 (1.1, 1.5)**	**1.3 (1.18, 1.44)**	**1.42 (1.28, 1.58)**	1.59(1.28, 1.97)	1.35 (0.94, 1.94)	1.2(0.96, 1.49)
		N = 23137	N = 23308	N = 23326	N = 7005	N = 7039	N = 7017
Hours spent gaming	0	REF	REF	REF	REF	REF	REF

		Past 2-week binge drinking[b]	Past 30-day drinking[b]	Past 30-day cannabis use[c]	Past 30-day flavor vaping[d]	Past 30-day cannabis vaping[c]	Past 30-day nicotine vaping[d]
	< 1	1 (0.81, 1.23)	0.91 (0.8, 1.03)	0.95 (0.81, 1.11)	0.77 (0.55, 1.08)	0.8 (0.5, 1.26)	1 (0.75, 1.34)
	1–2	0.92 (0.75, 1.13)	0.9 (0.8, 1.02)	0.92 (0.79, 1.07)	0.89 (0.64, 1.24)	0.67 (0.42, 1.07)	0.93 (0.7, 1.25)
	3+	0.96 (0.79, 1.16)	0.94 (0.84. 1.05)	1.02 (0.89, 1.17)	1 (0.74, 1.36)	0.7 (0.46, 1.06)	0.95 (0.72, 1.25)
		N = 24772	N = 24966	N = 24987	N = 6989	N = 7024	N = 7002
Hours spent watching videos: weekdays	0	REF	REF	REF	REF	REF	REF
	< 1	1.13 (0.84, 1.52)	1.12(0.93, 1.34)	0.92 (0.73, 1.14)	1 (0.6, 1.68)	1.88 (0.71, 4.98)	1.47 (0.93, 2.32)
	1–2	1.08 (0.82, 1.43)	1.12(0.94, 1.33)	0.95 (0.77, 1.17)	0.96 (0.59, 1.56)	2.24 (0.88, 5.67)	1.48 (0.96, 2.28)
	3+	1.18 (0.9, 1.54)	1.17(0.99, 1.39)	1.02 (0.83, 1.25)	1.16(0.72, 1.87)	1.94 (0.77, 4.87)	1.31 (0.86, 2.02)
		N = 24721	N = 24915	N = 24935	N = 6984	N = 7015	N = 6995
Hours spent watching videos: weekends	0	REF	REF	REF	REF	REF	REF
	< 1	1.14(0.83, 1.57)	1 (0.82, 1.23)	0.94 (0.76, 1.18)	1.28 (0.67, 2.44)	1.11 (0.43, 2.84)	1.45 (0.84, 2.5)
	1–2	0.89 (0.65, 1.21)	0.96 (0.79, 1.16)	0.87 (0.71, 1.07)	1.33 (0.74, 2.42)	1 (0.42, 2.39)	1.22 (0.72, 2.08)
	3+	0.8 (0.6, 1.07)	0.96 (0.8, 1.15)	0.84 (0.69, 1.01)	1.28 (0.72, 2.27)	0.89 (0.39, 2.06)	0.99 (0.59, 1.65)

All data are presented as aRR (95% CI). All models adjusted for grade, race/ethnicity, most recent GPA, and highest level of parental education received), past-year substance use, and assigned instrument form.

[a] Models with vaping outcomes only include 8th and 10th graders. Drugs included in "other drug" category vary by grade: for 12th graders we include LSD, other hallucinogens, cocaine, amphetamines, sedatives, tranquilizers, heroin, narcotics, crack, and other forms of cocaine. For 8th and 10th graders we do not include heroin, narcotics, or sedatives.

[b] Adjusted for past-year cannabis use, and other past-year drug use.

[c] Adjusted for past-year drinking, and other past-year drug use.

[d] Adjusted for past-year drinking, past-year cannabis use, and other past-year drug use.

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Table 3.

Poisson regressions predicting frequency of substance use by hours spent per day using digital media among 8th, 10th, and 12th graders in 2018[a]

		Past 2-week binge drinking[b]	Past 30-day drinking[b]	Past 30-day cannabis use[c]	Past 30-day flavor vaping[d]	Past 30-day cannabis vaping[c]	Past 30-day nicotine vaping[d]
		N = 1641	N = 3683	N = 2844	N = 753	N = 376	N = 873
Hours spent texting	0	REF	REF	REF	REF	REF	REF
	< 1	**−0.257 (−0.513, −0.001)**	**−0.435 (−0.551, −0.318)**	**−0.209 (−0.289, −0.129)**	**−0.202 (−0.354, −0.05)**	0.091 (−0.171, 0.354)	**−0.324 (−0.46, −0.187)**
	1–2	−0.132 (−0.385, 0.121)	**−0.34 (−0.456, −0.225)**	**−0.305 (−0.385, −0.225)**	**−0.24 (−0.391, −0.088)**	−0.075 (−0.341, 0.19)	**−0.297 (−0.433, −0.16)**
	3+	0.036 (−0.21, 0.281)	−0.084 (−0.197, 0.028)	**−0.268 (−0.345, −0.191)**	−0.078 (−0.223, 0.067)	0.004 (−0.25, 0.258)	**−0.201 (−0.334, −0.069)**
		N = 1624	N = 3657	N = 2821	N = 748	N = 373	N = 865
Hours spent talking on cell phone	0	REF	REF	REF	REF	REF	REF
	< 1	0.053 (−0.08, 0.187)	**0.15 (0.087, 0.213)**	**−0.129 (−0.168, −0.09)**	**−0.294 (−0.378, −0.211)**	0.008 (−0.141, 0.156)	**0.252 (0.178, 0.326)**
	1–2	**0.188 (0.048, 0.327)**	**0.23 (0.162, 0.299)**	**−0.077 (−0.119, −0.035)**	**−0.375 (−0.464, −0.285)**	0.079 (−0.072, 0.229)	0.057 (−0.025, 0.139)
	3+	**0.288 (0.147, 0.428)**	**0.446 (0.378, 0.514)**	**−0.05 (−0.093, −0.008)**	0.023 (−0.066, 0.111)	−0.105 (−0.259, 0.049)	**0.254 (0.171, 0.337)**
		N = 1628	N = 3655	N = 2818	N = 746	N = 375	N = 864
Hours spent social networking	0	REF	REF	REF	REF	REF	REF
	< 1	0.125 (−0.104, 0.354)	−0.054 (−0.158, 0.05)	−0.044 (−0.113. 0.026)	**−0.238 (−0.393, −0.082)**	−0.011 (−0.228, 0.206)	−0.048 (−0.189, 0.093)
	1–2	0.146 (−0.071, 0.363)	−0.093 (−0.191, 0.006)	−0.051 (−0.116, 0.014)	−0.111 (−0.254, 0.033)	0.068 (−0.132, 0.268)	**−0.15 (−0.284, −0.016)**
	3+	**0.294 (0.087, 0.501)**	**0.145 (0.052, 0.239)**	**−0.087 (−0.149, −0.025)**	−0.005 (−0.141, 0.132)	**−0.264 (−0.457, −0.071)**	−0.026 (−0.155, 0.104)
		N= 1638	N = 3672	N = 2823	N = 751	N = 376	N = 871
Hours spent video chatting	0	REF	REF	REF	REF	REF	REF
	< 1	0.056 (−0.031, 0.143)	**0.056 (0.012, 0.1)**	0.005 (−0.025, 0.035)	**−0.066 (−0.126, −0.006)**	**0.188 (0.1, 0.276)**	−0.019 (−0.068, 0.03)

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		Past 2-week binge drinking[b]	Past 30-day drinking[b]	Past 30-day cannabis use[c]	Past 30-day flavor vaping[d]	Past 30-day cannabis vaping[c]	Past 30-day nicotine vaping[d]
	1–2	0.033 (−0.072, 0.137)	0.013 (−0.04, 0.067)	**−0.21 (−0.248, −0.172)**	**−0.132 (−0.207, −0.056)**	**−0.216 (−0.333, −0.099)**	**0.143 (0.088, 0.198)**
	3+	**0.189 (0.086, 0.291)**	**0.304 (0.254, 0.354)**	−0.004 (−0.038, 0.029)	0.03 (−0.038, 0.097)	**0.22 (0.115, 0.325)**	0.037 (−0.027, 0.101)
		N= 1650	N = 3693	N = 2857	N = 757	N = 377	N = 875
Hours spent gaming	0	REF	REF	REF	REF	REF	REF
	< 1	**−0.171 (−0.303, −0.038)**	**0.012 (−0.055, 0.079)**	−0.018 (−0.069, 0.033)	**−0.18 (−0.293, −0.067)**	−0.08 (−0.245, 0.085)	**−0.375 (−0.452, −0.298)**
	1–2	**−0.226 (−0.357, −0.094)**	**−0 166 (−0.233, −0.099)**	**0.133 (0.084, 0.182)**	**−0.145 (−0.251, −0.039)**	0.045 (−0.114, 0.204)	**−0.369 (−0.446, −0.292)**
	3+	**−0.143 (−0.261, −0 026)**	−0.023 (−0.083, 0.037)	**0.14 (0.096, 0.185)**	0.023 (−0.075, 0.12)	**−0.171 (−0.321, −0.021)**	**−0.295 (−0.367, −0.224)**
		N = 1898	N = 4232	N = 3217	N = 755	N = 378	N = 871
Hours spent watching videos: weekdays	0	REF	REF	REF	REF	REF	REF
	< 1	−0.136 (−0.331, 0.06)	**−0.178 (−0.272, −0.084)**	**−0.141 (−0.202, −0.081)**	**−0.219 (−0.392, −0.045)**	−0.231 (−0.505, 0.043)	**−0.158 (−0.296, −0.019)**
	1–2	0.011 (−0.169, 0.19)	**−0.132 (−0.218, −0.045)**	**−0.23 (−0.285, −0.174)**	0.019 (−0.141, 0.18)	**−0.514 (−0.773, −0.256)**	−0.099 (−0.23, 0.032)
	3+	0.106 (−0.07, 0.281)	−0.014 (−0.099, 0.071)	**−0.184 (−0.238, −0.13)**	0.144 (−0.013, 0.301)	**−0.362 (−0.619, −0.106)**	**0.138 (0.009, 0.267)**
		N = 1894	N = 4219	N = 3209	N = 756	N = 379	N = 871
Hours spent watching videos: weekends	0	REF	REF	REF	REF	REF	REF
	< 1	−0.146 (−0.321, 0.028)	**−0.214 (−0.302, −0.126)**	**−0.202 (−0.265, −0.139)**	**−0.522 (−0.736, −0.307)**	**−0.297 (−0.519, −0.074)**	**−0.584 (−0.716, −0.453)**
	1–2	**−0.357 (−0.523, −0.191)**	**−0.52 (−0.603, −0.438)**	**−0.25 (−0.307, −0.193)**	−0.073 (−0.268, 0.123)	**−0.518 (−0.723, −0.313)**	**−0.711 (−0.837, −0.586)**
	3+	**−0.248 (−0.399, −0.096)**	**−0.481 (−0.555, −0.406)**	**−0.278 (−0.33, −0.226)**	−0.135 (−0.324, 0.054)	**−0.527 (−0.719, −0.335)**	**−0.609 (−0.728, −0.49)**

All data are presented as expected log count (95% CI). All models adjusted for grade, race/ethnicity, most recent GPA, and highest level of parental education received), past-year substance use, and assigned instrument form.

[a]Models with vaping outcomes only include 8th and 10th graders. Diugs included in “other drug” category vary by grade: for 12th graders we include LSD, other hallucinogens, cocaine, amphetamines, sedatives, tranquilizers, heroin, narcotics, crack, and other forms of cocaine. For 8th and 10th graders we do not include heroin, narcotics, or sedatives.

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[b]Adjusted for past-year cannabis use, and other past-year drug use.

[c]Adjusted for past-year drinking, and other past-year drug use.

[d]Adjusted for past-year drinking, past-year cannabis use, and other past-year drug use.