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Use of digital phenotyping to understand digital media influence on adolescent substance use

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BOSTON UNIVERSITY

ARAM V. CHOBANIAN & EDWARD AVEDISIAN SCHOOL OF MEDICINE

Thesis

**USE OF DIGITAL PHENOTYPING TO UNDERSTAND DIGITAL MEDIA
INFLUENCE ON ADOLESCENT SUBSTANCE USE**

by

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B.S., Villanova University, 2023

Submitted in partial fulfillment of the
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DEDICATION

I would like to dedicate this work to my brother Darshan. I would not be the person I am without you! I love you more than anything

ACKNOWLEDGMENTS

I would like to thank Dr. Meredith Gansner for all her support and guidance throughout this project. Having her as my incredible mentor has been invaluable and I cannot express enough how much of an impact she has made on my life. I am forever grateful for the opportunity to be a part of her research.

I would also like to thank Dr. Beth Bragdon for helping, caring, and guiding me through these past two years. You have been an incredible advisor and have offered me the best advice and insight for my studies and future. I deeply appreciate all of your time and help.

Lastly, I would like to thank the Gansner research team for all their continued support and effort to help me on this project.

I would also like to thank my amazing family of Darshan, Dad, Mom, and Karthik for their unwavering support. I would also like to thank my amazing close friends for always being there for me and being a great support system.

**USE OF DIGITAL PHENOTYPING TO UNDERSTAND DIGITAL MEDIA
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ABSTRACT

Many risk factors appear to influence adolescent use of drugs and alcohol, including digital media use. Multiple studies have demonstrated significant associations between an adolescent's time spent online, exposure to drug and alcohol-related content, and individual substance use. However, the exact nature of this relationship is unclear, including what type of drug-related content exposure may confer greater risk, and whether the amount and timing of drug-related online exposures also impact the strength of this relationship.

This is a smartphone app-based ecological momentary assessment (EMA) study that collected 90 days of longitudinal data from U.S. youth aged 15-20 years old with a history of recent but non-daily substance use. Data included daily smartphone app usage, exposure to substance-related content online, and daily instances of substance use. Mixed effects logistic and linear regression models assessed temporal relationships between substance-related content exposures and instances of substance use/procurement.

Data was collected from 62 individuals, with 60.3% of participants identifying as white non-hispanic/latine. Most participants identified as female (75.8%) with the average age of the participant being 18.6 years of age. Cannabis use was the most frequently reported type of substance use, followed by alcohol and nicotine use. The online platforms reportedly used most were Instagram, TikTok, and Snapchat. Daily

online exposures to substance-related content and instances of substance use were significantly correlated (OR: 1.32, p: 0.025), as well as the total number of exposures to substance-related content and substance use (Coeff: 0.031, p: 0.027). There was no significant correlation between substance use and exposure to substance-related online content the day prior to an instance of substance use (OR: 1.05, p:0.666). Furthermore, there was no significant relationship between substance procurement and substance-related online content exposures (OR:1.17, p:0.326).

Exposure to drug and alcohol-related content appear to significantly increase an individual's odds of substance use on that day, and instances of substance use correlated with a greater number of substance-related exposures on that day. Future studies should explore whether the strength of this relationship varies dependent upon specific types of substance-related exposures (e.g. video vs. text-based, social media vs. website).

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LIST OF ABBREVIATIONS

DP	Digital Phenotyping
EMA.....	Ecological Momentary Assessment

INTRODUCTION

Background

As digital media use increasingly becomes an integral part of individuals' daily lives, more and more children and adolescents report regular access to digital devices/platforms. In surveys of U.S. teens, 96% report using the internet daily (Pew Research Center, 2024). In a survey sample of young adolescents attending public schools in a large Southeastern U.S. state, close to half (48%) of 11-year-olds reported owning a mobile phone with a steep increase in ownership by the age 14, to 85% of adolescents (Odgers, 2018). By mid-late adolescence, 98% of teenagers report having access to a smartphone (Pew Research Center, 2024).

As these digital technologies become more accessible to children and adolescents, the amount of time youth spend using them is increasing as well. In the United States, adolescents are estimated to spend 6.7 hours per day viewing online screen media for non-school purposes (Rideout, 2018). Nearly half of U.S. teens report that they are online "almost constantly" (Pew Research Center, 2024). **Figure 1** below shows how internet use among U.S. teens has evolved from 2014-2015 to 2024. The mediums in which teenagers have used to access the internet has changed as well. The amount of teenagers who have access and are using tablets has risen over the years from 65% to 70% (Pew Research Center, 2024).

% of U.S. teens ages 13 to 17 who say they use the internet ...

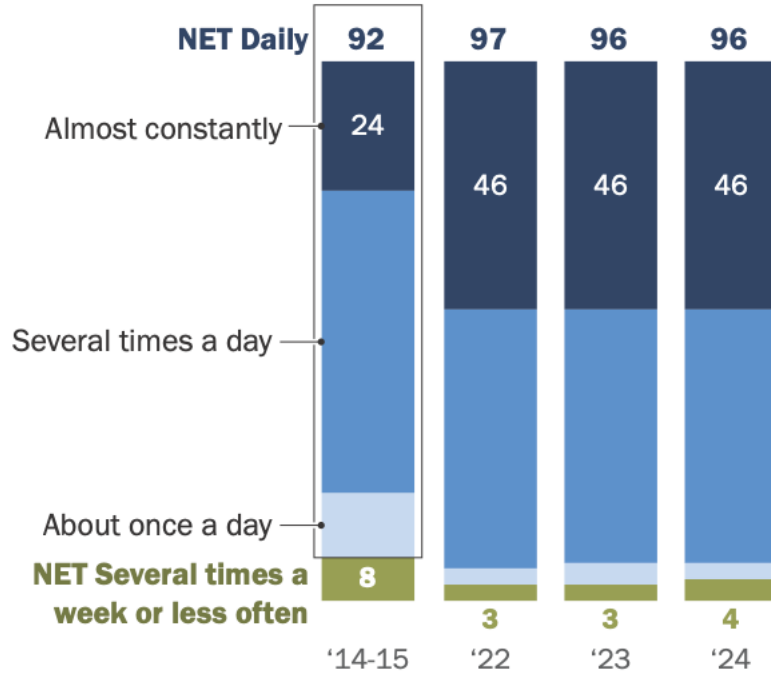


Figure 1: Percentage of U.S. Teens ages 13 to 17 who use the internet

Obtained from Pew Research Center, 2024

% of U.S. teens ages 13 to 17 who say they have or have access to the following devices at home

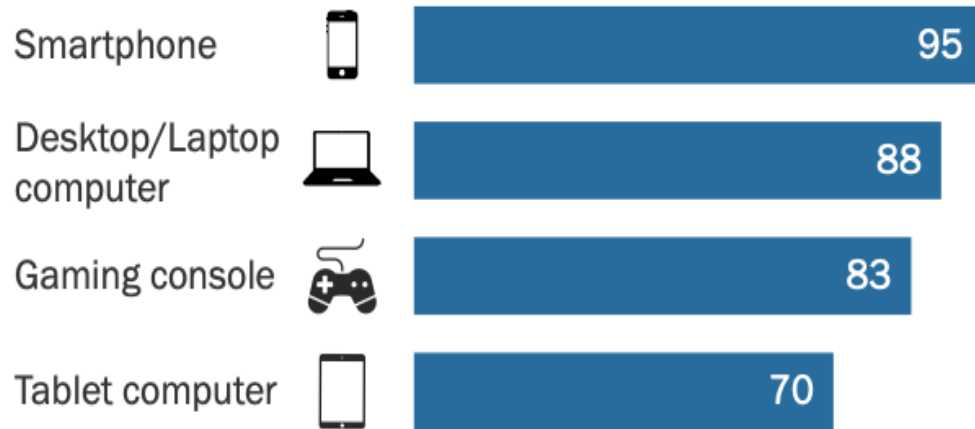


Figure 2: Percentage of U.S. Teens ages 13 to 17 who have access to the following devices Obtained from Pew Research Center, 2024

Adolescent Social Media Use

Through the internet, social media platforms have dramatically altered the way humans communicate and form relationships (Rajamohan, 2019). Social media offer users a means of connection with others, both expediently and efficiently. Social media help youth form connections with others and strengthen existing friendships (Pew Research Center, 2018). Data has shown that social media use specifically is nearly ubiquitous among adolescents, (Vogels, 2022). Currently popular social media platforms are TikTok, Snapchat, Instagram, YouTube, Reddit, and Twitter. YouTube is reported to be used by 9 out of 10 teens, with 73% of teens stating that they go on YouTube daily (Pew Research Center, 2024). Likewise, six in ten teens report using both TikTok and

Instagram, and Snapchat use is reported by approximately 55% of U.S. teens (Pew Research Center, 2024). At present, the least popular social media applications among teens are Reddit (14%) and WhatsApp (23%) (Pew Research Center, 2024). Changing trends in social media usage among U.S. teens from 2014-15 to 2024 are depicted in

Figure 3

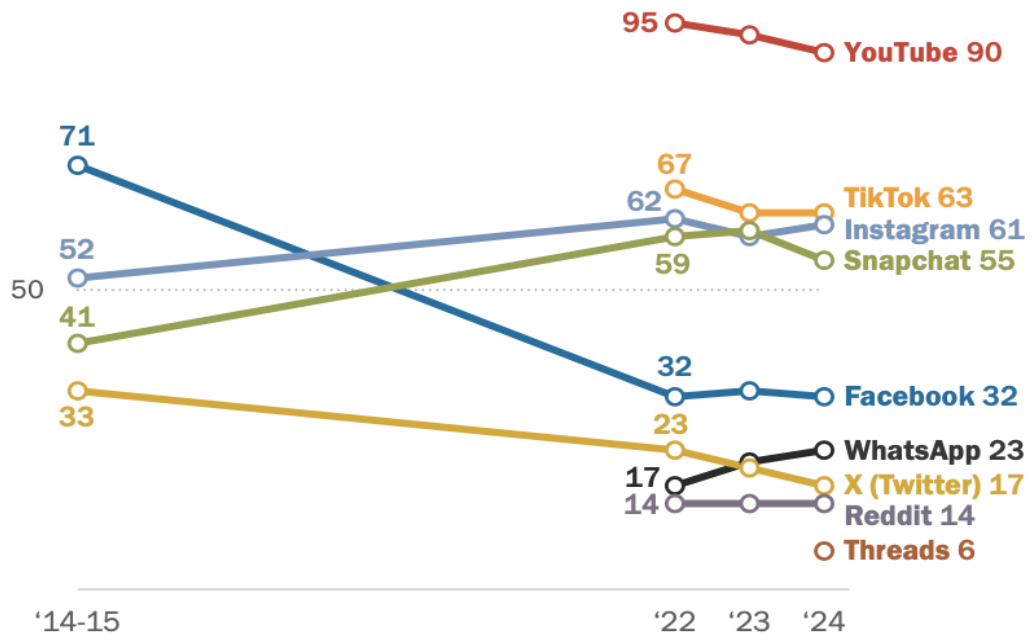


Figure 3: Percentage of U.S. Teens ages 13 to 17 who use media platforms.

Obtained from Pew Research Center, 2024

% of U.S. teens ages 13 to 17 who say they visit or use the following apps or sites ...

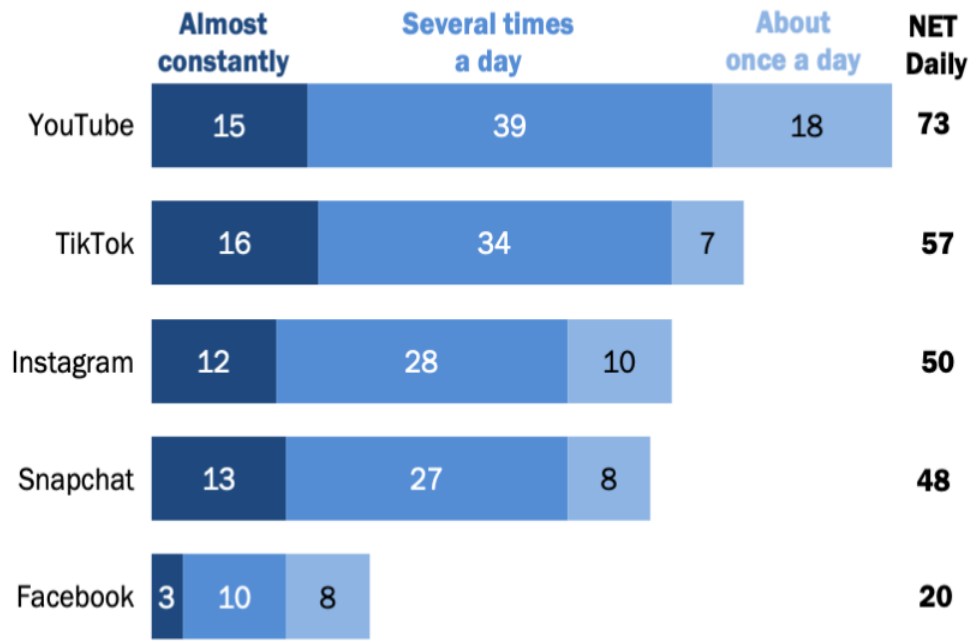


Figure 4: Percentage of U.S. Teens 13-17 who use social media platforms.

Obtained from Pew Research Center, 2024

Social media applications differ in both the type of digital content they feature as well as what mechanisms can be used for communication with others (e.g. direct messaging vs. public posts). For example, TikTok and YouTube allow users to post videos that viewers can interact with/respond to. Instagram allows users to post both pictures and videos but with a greater emphasis on building connections with friends and other individuals (Turner, 2017). Similarly, Snapchat allows users to exchange photos and videos, but more through use of ephemeral direct (private) messaging as opposed to public posts (Majmundar, 2021).

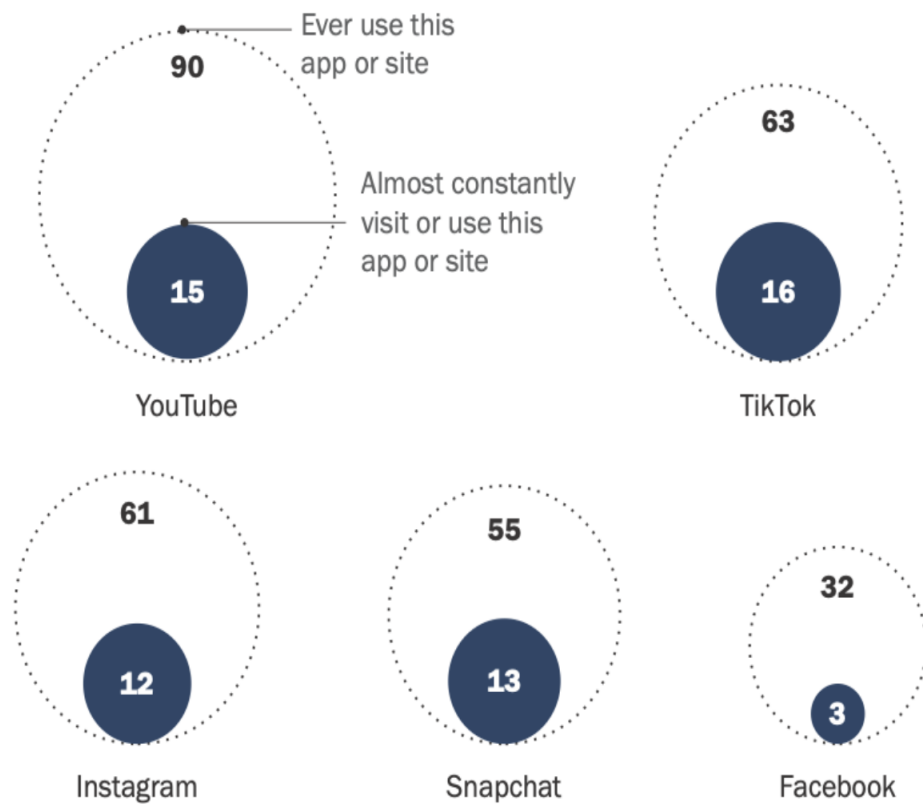


Figure 5: Percentage of US Teens 13-17 who have ever used a certain social media app or site and who almost constantly use a certain social media app or site. Obtained from Pew Research Center, 2024

Social Media Contagion

Unfortunately, the design of social media platforms may be problematic for vulnerable teenagers. For one, these platforms are an effective vehicle for social contagion (Gansner, 2024). The American Psychological Association defines social contagion as, “the spread of behaviors, attitudes, and affect through crowds and other types of social aggregates from one member to another” (American Psychological Association, 2018). Social contagion can amplify the spread of information between networks, communities, and individuals, and information is capable of spreading regardless of whether the information is harmful or health-promoting (Hodas, 2014). Social media contagion is a more recent phenomenon, but media have long been recognized as drivers of social/behavioral contagion (Gansner, 2024). Social media platforms are particularly effective at promoting social contagion because they create both an optimal environment for the spread of behaviors/cognitions and reach an extensive network of susceptible viewers (Gansner, 2024). Similar to how a virus uses a particular mechanism to spread throughout a desired population, with amplification in favorable environments, social contagion is hypothesized to occur similarly. (Guzman, 2015).

Social contagion is often attributed to mechanisms like descriptive and injunctive norms (Nicolls, 2022). Descriptive norms refer to the perceived prevalence of a given behavior, whereas injunctive norms refer to the extent to which others approve of a given behavior (LaBrie, 2010). Via theories of descriptive and injunctive norms, individuals may be more likely to engage in risky activities that they perceive “everyone else” to be

doing, or risky activities that would gain them approval from their peers. For example, injunctive norms have been implicated as a significant driver of drug-related behaviors among teens (Carey, 2020).

Social media platforms use algorithms to select viewers' content for them, and these algorithms are based on the viewer's previously selected content (Yeung, 2022). Thus, social media algorithms can make it challenging for users to avoid encountering certain types of content that they might have previously displayed an interest in. This is particularly concerning because there is a wide range of unmoderated, user-generated social media content that might be harmful for adolescents to visualize (Yeung, 2022). For example, a teenager who may have expressed a one-time interest in cannabis-related content may be liable to being repeatedly shown more cannabis-related content. These repeated exposures to cannabis-related content may lead a teenager to use cannabis based on their belief that "everyone else" is using it (via descriptive norms), even if this is not actually the case.

On social media platforms, teenagers also risk encountering groups or forums with non-diverse viewpoints surrounding engagement with high-risk behaviors, often referred to colloquially as echo chambers. Echo chambers can be defined as online communities wherein members's opinions/beliefs about a topic are (potentially incorrectly) reinforced due to repeated interactions with only online peers who share those same opinions/beliefs (Cinelli, 2021). For example, echo chambers like drug-related online forums could promote substance use by artificially making drug use appear prevalent among others (descriptive norms) and socially desirable (injunctive norms).

Adolescents may be especially susceptible to mechanisms of descriptive/injunctive norms because they are at a developmental stage where they seek both validation and belonging (Popat, 2022).

Finally, social media algorithms do not necessarily distinguish between online content that “promotes” drug use and content that “prevents” drug use. These algorithms focus primarily on the goal of increasing user engagement (Yeung, 2022). Recommended content is selected based not upon viewer safety but odds of viewer engagement. Regardless of whether or not social media content could inflict harm on some viewers, if content drives a high level of interaction, algorithms may continue to recommend this material (Costello, 2024). Therefore, even if a teenager goes online for support to stop using drugs or alcohol, it is possible that they could be shown substance-related content that inadvertently promotes substance use.

Examples of Adolescent Social Media Contagion

Social media contagion has already been implicated in adolescent substance use, non-suicidal self-injury, disordered eating, suicidal behavior, and violence (Memon, 2018). For example, non-suicidal self-injury social media content is thought to reinforce cutting behaviors through graphic imagery and promoting “competition” in self-injury. Nonsuicidal self-injury (NSSI) refers to the intent of destruction of one’s body without the intent of suicide. This can range from things such as cutting, burning, or bruising. This hurting of oneself is usually described from the destruction of one’s tissue. (Nock, 2009). This has raised a societal concern in regards to the negative effects that exist

between individuals who self-harm (Lewis, 2016). Nonsuicidal self-injury has become a prominent health concern among adolescents. It was reported that between 14% and 24% of youth are reported to partake and report that they self-injure at least once in their lifetime (Rodham, 2009). Exposures to this nonsuicidal self-injury has been reported to elevate the risk for psychological difficulties the more individuals engage with this type of content (Lewis, 2016). Furthermore, it was found that content of content that was posted online showed that individuals looked to seek other individuals who had also partaken in similar experiences (Lewis, 2016). As content pertaining to nonsuicidal self-injury was found and became more exposed, some individuals became more susceptible to partake in nonsuicidal self-injury. (Baker, 2013). This can be seen due to adolescence being a vulnerable time for youth, especially to engage in maladaptive behaviors (Lewis, 2016).

Additionally, content promoting disordered eating is also prevalent on social media, attributed in part to social media filters promoting unrealistic beauty standards (Javornik, 2021), and this content exposure can lead to frequent self-comparison and a negative body image.. Augmented reality filters beautify the subject to enhance their image (Vendemia, 2018), and engagement with this type of photo editing has been connected to thin ideal internalization, self-objectification, and a drive for thinness among young women (Meier, 2014). Various advertisements and content exposures on these platform circle back to promote these unrealistic beauty standards. Social media influencers are a key promoter of this standards as they can heavily influence body dissatisfaction in adolescents that are more susceptible to this type of content (Quick, 2013). This can lead to and cause eating disorders in adolescents. Eating disorders are

psychiatric disorders characterized by a behaviors that include abnormal eating patterns and weight-control. Attitudes towards weight body shape have been reported to play a major role in eating disorders (Treasure, 2020).

Adolescent Substance Use & Exposure to Drug-Related Content Online

As per the National Center on Addiction and Substance Abuse, adolescent substance abuse is a prevalent public health problem, even though rates are falling overall. By senior year, almost 70% of high school students will have tried alcohol, 50% will have taken an illegal drug, nearly 40% will have smoked a cigarette, and more than 20% will have misused a prescription drug for a nonmedical purpose (Garfoli, 2020). Occasionally, this substance use can have significant medical consequences or even result in death. Despite decreasing rates of substance use, adolescents experienced a greater relative increase in overdose mortality attributable in large part to fatalities involving fentanyl-contaminated, unregulated prescription medications (Friedman, 2022). Rising adolescent overdose rates, and their connection to social media use, make it especially critical to understand how youth are exposed to drug-related content online, and what online exposures might influence their decision to engage in substance use. Social media platforms have been implicated in increasing access to fentanyl-tainted prescription drugs, resulting in multiple overdoses and deaths, even in those without formal substance use disorders. In 2021, fentanyls were found to play a role in 77.14% of adolescent overdose deaths (Friedman, 2021).

Growing research evidence suggests that youth exposure to drug and alcohol-related content online is not uncommon (Moyle, 2018). For example, it has been reported

that 52.8% percent of adolescents have been exposed to marijuana related content online (Dai, 2017). Gansner et al. 2024 found that nearly 75% of surveyed youth reported exposure to drug-related content online during the course of the study, with exposures taking a variety of different forms (Gansner, 2024).

Exposure to this substance-related online content has also been connected to higher rates of substance use. Increased exposure to pro-alcohol- and marijuana-use content has been significantly associated with a greater likelihood of heavy episodic drinking and marijuana use (Cabrera-Nguyen, 2016). Online content promoting alcohol use increases the likelihood that adolescents will start to use alcohol or drink more if they already engage in alcohol use (Anderson, 2009). E-cigarette placement in music videos has been associated with vaping among young adults (Majmundar, 2021). And in their pilot study, Gansner et al. found that participants had higher odds of substance use on days that they were exposed to substance-related content posted by their peers (Gansner, 2024).

Even if an adolescent does not intentionally or actively seek out drugs or alcohol online, self-disclosure of negative emotions over social media platforms may increase their chances of a) being targeted as a potential buyer of drugs/alcohol or b) being offered drugs/alcohol by peers.

However, there still remain many unknowns regarding the nature of this online exposure/substance use relationship. Many prior studies in this area are cross-sectional in

nature, making it challenging to ascertain the directionality of the relationship (i.e. are teens who use drugs and alcohol simply more likely to visualize substance-related content online?). One-time surveys are also limited by self-report and recall bias. Furthermore, even if drug-related online exposures do influence adolescents to use substances, it is unclear how long the effect might last (i.e. could drug-related online exposures influence episodes of substance use beyond just the day of exposure).

To address these potential limitations, this current study proposes use of a smartphone-based ecological momentary assessment protocol. To our knowledge, no other study has investigated temporal associations between substance-related online content exposures and instances of both substance use and procurement events, including whether timing of the exposure and number of exposures impact potential degree of influence. Here, we propose to examine temporal relationships between substance-related online exposures and 1) same-day instances of substance use, 2) following-day substance as well as whether there is correlation between instances of substance use and higher numbers of substance-related exposure on that day. We also propose to examine the relationships between substance-related online exposures and substance procurement (any procurement, an procurement via digital media and social media).

We expected to find a direct correlation between same-day substance-related online exposures and instances of substance use, as well as significant relationship between instances of substance use and a greater number of exposures of same-day substance-related online exposures. Given recent concerns about adolescent procurement

of drugs via digital media (particularly social media), we also hypothesized that there would be significant higher odds of substance procurement via social media on days with exposures to substance-related online content.

Methods

Study Design

Overall Study Design

This was a 90-day EMA study that collected data on 62 U.S. teenagers (aged 15-20 years old) with a history of recent but non-daily substance use in the three months prior to recruitment. The study used the digital phenotyping smartphone application EARS for data collection (Ksana Health, 2024). Because this study used national recruitment, all participants completed study procedures remotely. Meetings between the study team and participants were held via Zoom in accordance with hospital policy guidelines at the primary study site.

Recruitment Methods

Recruitment was overseen by research staff who had completed web-based Collaborative IRB Training Initiative (CITI) training. Participants were recruited using a REDCap survey URL link administered via Facebook advertising methods (the ad would be displayed through Facebook, Instagram, and Facebook marketplace), modeled on prior studies of youth substance use (Thornton, 2016). When prospective participants clicked on the study advertisement, they were directed to a secure REDCap survey. In addition to social media advertising, the study team also distributed a flyer with study information to national listservs of adolescent medicine clinicians as well as in Boston and the greater Boston area. This flyer had a QR code that linked to the secure REDCap survey mentioned above.

The REDCap survey asked potential participants to input only their cell phone number. Within 24 hours of receiving a potential participant's phone number, a study

staff member would delete the number from the REDCap database.



Where the world comes for answers

SEEKING PARTICIPANTS FOR A PAID RESEARCH STUDY

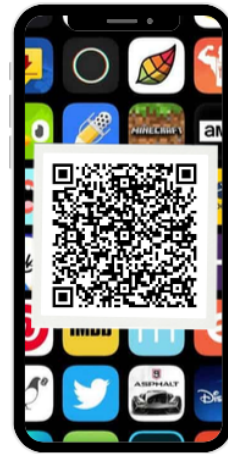
We are currently recruiting youth participants for a virtual research study about the relationship between **social media use** and **health related behaviors**.

This study is **completely remote** and involves:

- Downloading a smartphone app to track your daily digital media use for 90 days.
- Completing quick daily and weekly surveys using the app.
- Surveys take less than 5 minutes per day

Who is eligible?

- Between 15 and 20 years old at the time of consent/ assent.
- Fluent in English
- Has access to a smartphone



If you are interested, please scan the QR code or follow this link to provide your contact information:

<https://shorturl.at/jiFmJ>

Participants can receive up to \$250 for participation!

Figure 6: The study flyer that was distributed for the study

Once a prospective participant's cell phone number was received, a study team member texted the participant via the smartphone application Doximity (a secure HIPAA-compliant texting app). This text message scheduled an initial virtual meeting to check if the individual was eligible for the study. If an interested individual was under 18 and eligible, the team then scheduled a second call with both the participant and their legal guardian/parent to complete the consent/assent process and enrollment. If an interested individual was eligible and 18 years of age or older, the team would either proceed with the consent process during the initial meeting if time permitted, or schedule a second meeting for consent/enrollment.

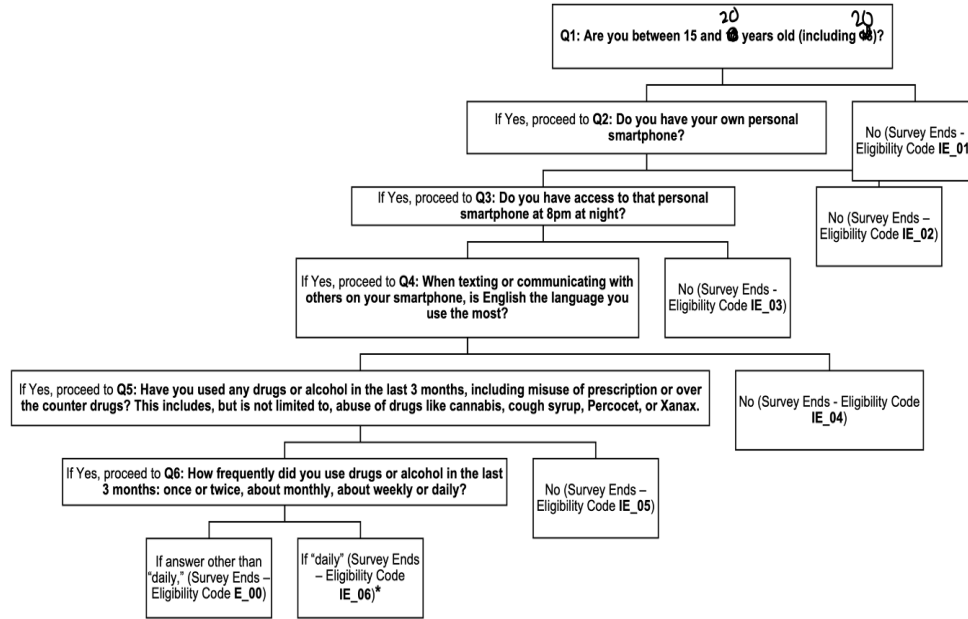


Figure 7: The eligibility phone call script used to screen potential participants

Eligibility Criteria

Study participants could identify as male, female or non-binary, and any race/ethnicity, but had to be between the ages of 15-20 years old at the time of consent/assent, as well as fluent in English. Participants also needed to have a personal smartphone that they could access during the hours of 8pm and midnight on a daily basis, and report a history of any instance of drug or alcohol use in the three months prior to enrollment. Interested participants reporting daily substance use over the last three

months were excluded from participation. Participants under 18 years old were also excluded if the team was unable to obtain a parent or/guardian's consent.

Consent Process

Consent/assent meetings were conducted virtually via Zoom or another form of video conferencing deemed acceptable as per hospital policy. Electronic consent/assent forms were stored securely on the hospital server at the primary study site. After the consent process was completed, participants or guardians received a copy of the consent form for their records. All modes of communication and document transfer were HIPAA compliant.

Study Procedure

Following the informed consent process, participants downloaded the EARS application and took part in a 90-day EMA protocol. EMA surveys were delivered to the participants' cell phone daily at 8 PM, and participants received a push notification reminding them of the need to complete their daily survey. Participants had until midnight the subsequent day to complete the daily surveys (a 4-hour window). Table 1 displays the contents of the daily surveys. Participants were asked to answer questions regarding daily social media use using their daily screen time report generated by their smartphone.

3. TODAY, how many times did you see **any** online content related to drugs or alcohol?
 - a. Never
 - b. 1-5 times
 - c. 6-10 times
 - d. More than 10 times

4. TODAY, how many times did you see ONLINE ADVERTISEMENTS for drugs or alcohol?
 - a. Never
 - b. 1-5 times
 - c. 6-10 times
 - d. More than 10 times

5. TODAY, how many times did you see ONLINE VIDEOS that mentioned drugs or alcohol (e.g. videos on YouTube or TikTok)?
 - a. I didn't watch online videos today
 - b. Never
 - c. 1-5 times
 - d. 6-10 times
 - e. More than 10 times

Figure 8: Part of the Daily EMA survey

Substance Procurement Questionnaire:

1. TODAY, did anyone contact you ONLINE or over SOCIAL MEDIA about purchasing or accessing drugs or alcohol?

- Yes
- No

2. TODAY, did anyone contact you through a DIRECT MESSAGE or TEXT about purchasing or accessing drugs or alcohol?

- Yes
- No

3. TODAY, did you obtain drugs or alcohol in any way?

- Yes
- No

3b. If yes to question #3:

TODAY, did you use digital media to access drugs or alcohol from someone you know (e.g. friend or family member)?

- Yes
- No

3c. If yes to question #3:

TODAY, did you purchase or obtain drugs or alcohol using a social media platform?

- Yes
- No

Figure 9: Substance Procurement Questionnaire

2. In the past DAY, how many times have you used alcohol?

- A. Never
- B. Once
- C. More than once

3. In the past DAY, how many times have you used marijuana (such as smoking, vaping or edibles)?

- A. Never
- B. Once
- C. More than once

4. In the past DAY, how many times have you used prescription drugs that were not prescribed to you (such as pain medication or Adderall)?

- A. Never
- B. Once
- C. More than once

4b: If participant answers B or C to question #4:

Which prescription drug(s) did you use that **were not prescribed to you** (choose all that apply)?

- A. Stimulant (like Adderall, Ritalin, Vyvanse)
- B. Pain medication (like Percocet, Vicodin)
- C. Sedative (like Xanax, Ativan)

5. In the past DAY, how many times have you used illegal drugs (such as cocaine, Ecstasy or Molly)?

- A. Never
- B. Once
- C. More than once

5b: If participant answers B or C to question #5:

Which illegal drugs did you use (choose all the apply)?

- A. Cocaine
- B. Ecstasy (Molly)
- C. LSD
- D. Heroin
- E. Other

6. TODAY, how many times have you used inhalants (such as nitrous oxide)?

- A. Never
- B. Once
- C. More than once

7. TODAY, how many times have you used herbs or synthetic drugs (such as salvia, "K2", or bath salts)?

- A. Never
- B. Once
- C. More than once

Figure 10: s2bi Questionnaire

To assess for nonparticipation in EMA surveys, study personnel reviewed whether the participant responded to EMA surveys responses through the EARS app dashboard at the end of each 10-day period. If the participant responded to the EMA surveys less than 5 times in that 10-day period, study personnel reached out to participants via an outreach email (or text if they have consented to this form of contact) At most, these reminders were only sent once per 10-day study period.

Survey/Scale	Measure	Description of measure
Social Media Use & Substance-related online content exposure questionnaire	Questions pertaining to social media use & exposure to drug and alcohol-related content online	This questionnaire contained 11 questions pertaining to daily social media use and various intentional and unintentional digital media exposures to drug and alcohol-related content. It has been used by this PI in past survey studies and EMA protocols.
Modified S2BI questions	Assessed daily substance use	The Modified S2BI questions assessed for presence or absence of alcohol, cannabis or other drug use. It was modified here to account for daily use.

Substance procurement questionnaire	Assessed daily substance procurement	This questionnaire is made up of 4 questions inquiring about whether the participant was contacted online about purchasing/acquiring drugs or alcohol, whether the participant purchase/acquired drugs or alcohol, and whether that occurred via digital media or social media.
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Table 1. Daily EMA Questions (In Order of Administration)

Participant Compensation

All the participants in the study had the opportunity to earn up to \$250 over the course of the study: they received \$35 upon study enrollment after completing the consent process and after downloading the EARS application, and another \$35 after completing the study at the end of 90 days. Participants received either \$10 and \$20 ever 10 days depending upon percentage of surveys completed in that 10-day period. Participants who completed 50% of more of the surveys in that 10-day period received \$20, and those who completed less that 50% received \$10.

Results

Data was collected from 62 individuals, with 60.3% of participants identifying as white non-hispanic/latine. Most participants identified as female (75.8%) with the average age being 18.6 years of age. Cannabis use was the most frequently reported type of substance use, followed by alcohol and nicotine use. The online platforms used most were Instagram, TikTok, and Snapchat.

Variable	Percentage (%)
Gender	
Male	24.2%
Female	75.8%
Race/Ethnicity	
White (non-hispanic/latine)	60.3%
Asian	1.61%
Multi-Racial	8.06%
Hispanic/Latine	9.68%
Black (non-hispanic/latine)	12.9%

Table 2: The Demographic breakdown of the study

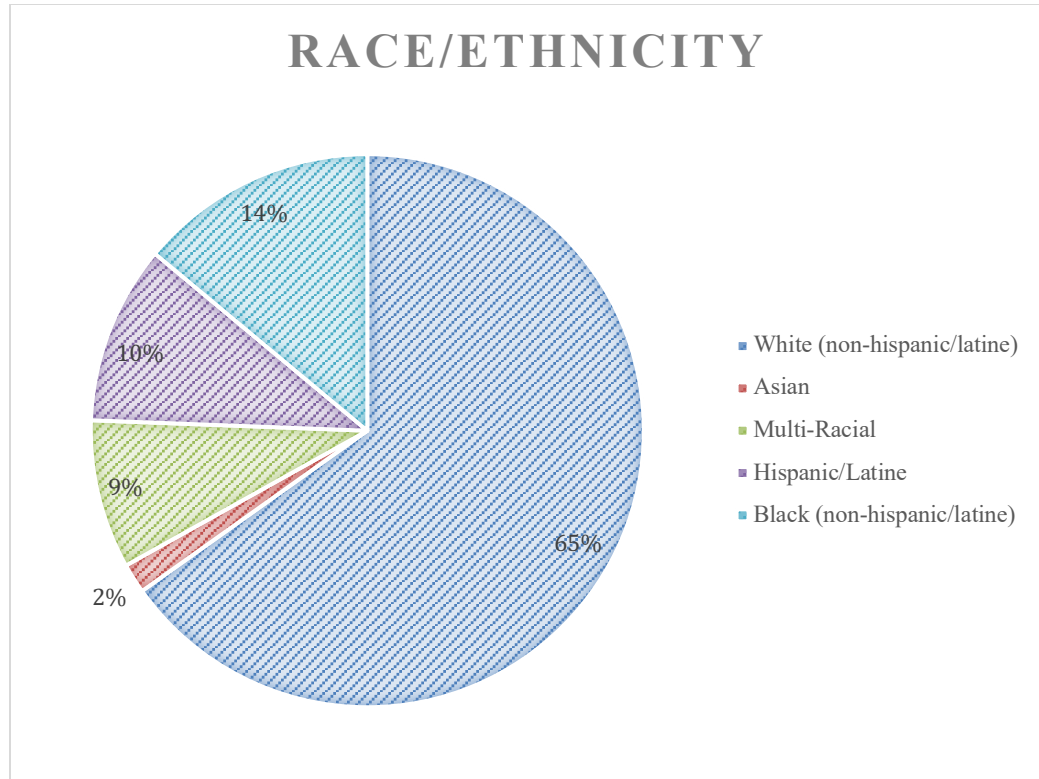


Figure 11 : Demographic distribution of the study

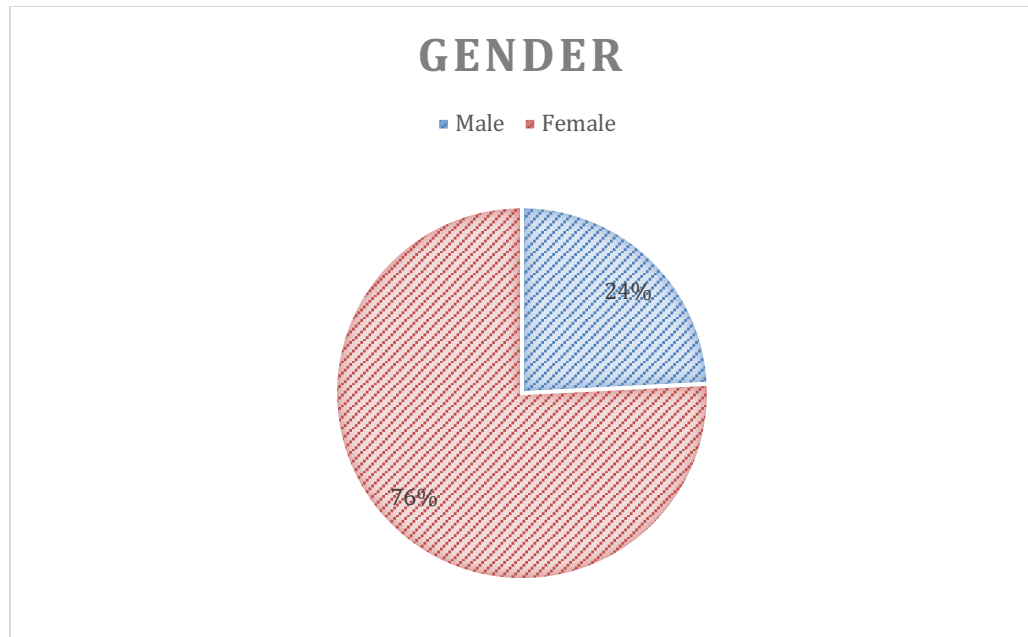


Figure 12: Gender distribution of the study

Mixed-effects logistic regression models were conducted to assess the relationship between instances of substance use and 1) same-day substance-related online exposures, 2) prior-day substance-related online exposures, 3) same-day substance procurement, 4) same-day substance procurement via digital media, and 5) same-day substance procurement via digital media. A mixed-effects linear regression model was performed to assess if there was any correlation between instances of substance uses and greater numbers of same-day substance-related online exposures. A 95% confidence interval was used for these tests. The results of these analyses are found in **Table 3 & 4** below (with a * denoting $p < 0.05$).

	Odds Ratio	Confidence Intervals	Standard Error	p-value
Exposure(same day) and substance use	1.32	1.04, 1.68	0.163	0.025*
Exposure (day before) and substance use	1.05	0.83, 1.34	0.130	0.666
Exposure (same day) and procurement	1.17	0.86, 1.59	0.182	0.326
Exposure and Procurement via Digital Media	1.01	0.49, 2.11	0.378	0.975
Exposure and Procurement via Social Media	2.15	0.75, 6.16	1.15	0.154

Table 3: Relationship between Substance-Related Online Exposures & Instances of Substance Use and Procurement

	Coeff.	Confidence Intervals	Standard Error	p-value
Number of exposures and substance use	0.031	0.0035, 0.058	0.0140	0.027*

Table 4: Relationship between Substance-Related Online Exposures & Number of Substance-Related Online Exposures that Same Day

Substance-Related Online Exposures and Substance Use

Same-day exposure to substance-related content was significantly correlated with instances of substance use ($p=0.025$). This suggests that adolescents that were exposed to substance-related content on a given day would be 32% more likely to engage in substance use that same day compared to individuals who were not exposed to substance related content. Exposure that occurred on the previous day did not correlate significantly with instances of substance use ($p=0.666$). There was a positive correlation between number of substance-related exposures on a particular day and instances of substance use on that day ($p=0.027$).

Exposure and Procurement

Results indicated that exposure to substance-related content was not associated with greater odds of substance procurement.

The table below (**Table 5**) shows the breakdown of the total number of uses between the different substances

Substances	Total Uses
Cannabis	582
Alcohol	540
Nicotine	354
Prescription Drugs	18
Stimulants	10
Illegal Drugs	9
Sedatives	5
Pain Medication	3
Inhalants	3
Synthetic Drugs	1

Table 5: Total instances of different types of drugs or alcohol reported by participants

Substance Use Reported by Study Participants

Substances that were reported most frequently were cannabis, alcohol, and nicotine. The bar graph below (**Figure 13**) is a graphic representation of the data reported in **Table 5** above. The Pie chart below (**Figure 14**) shows the percentage breakdown of each substance respectively.

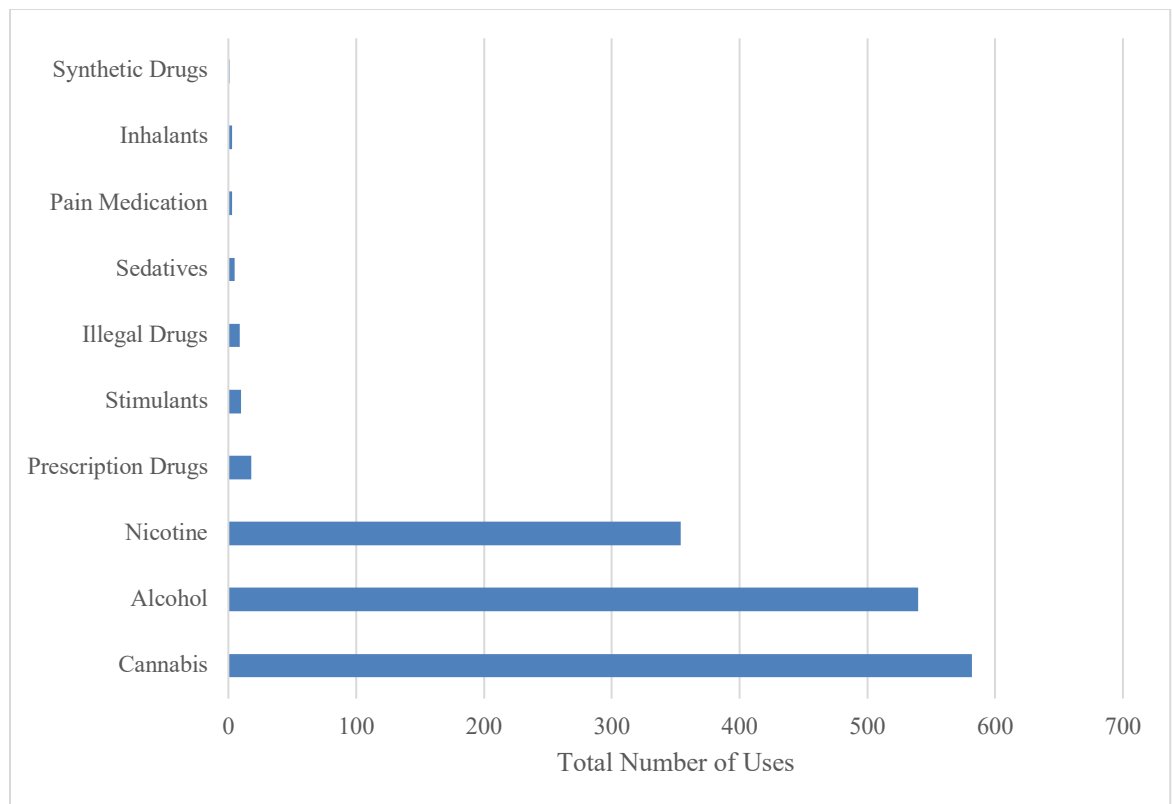


Figure 13: Total number of uses reported per each individual substance

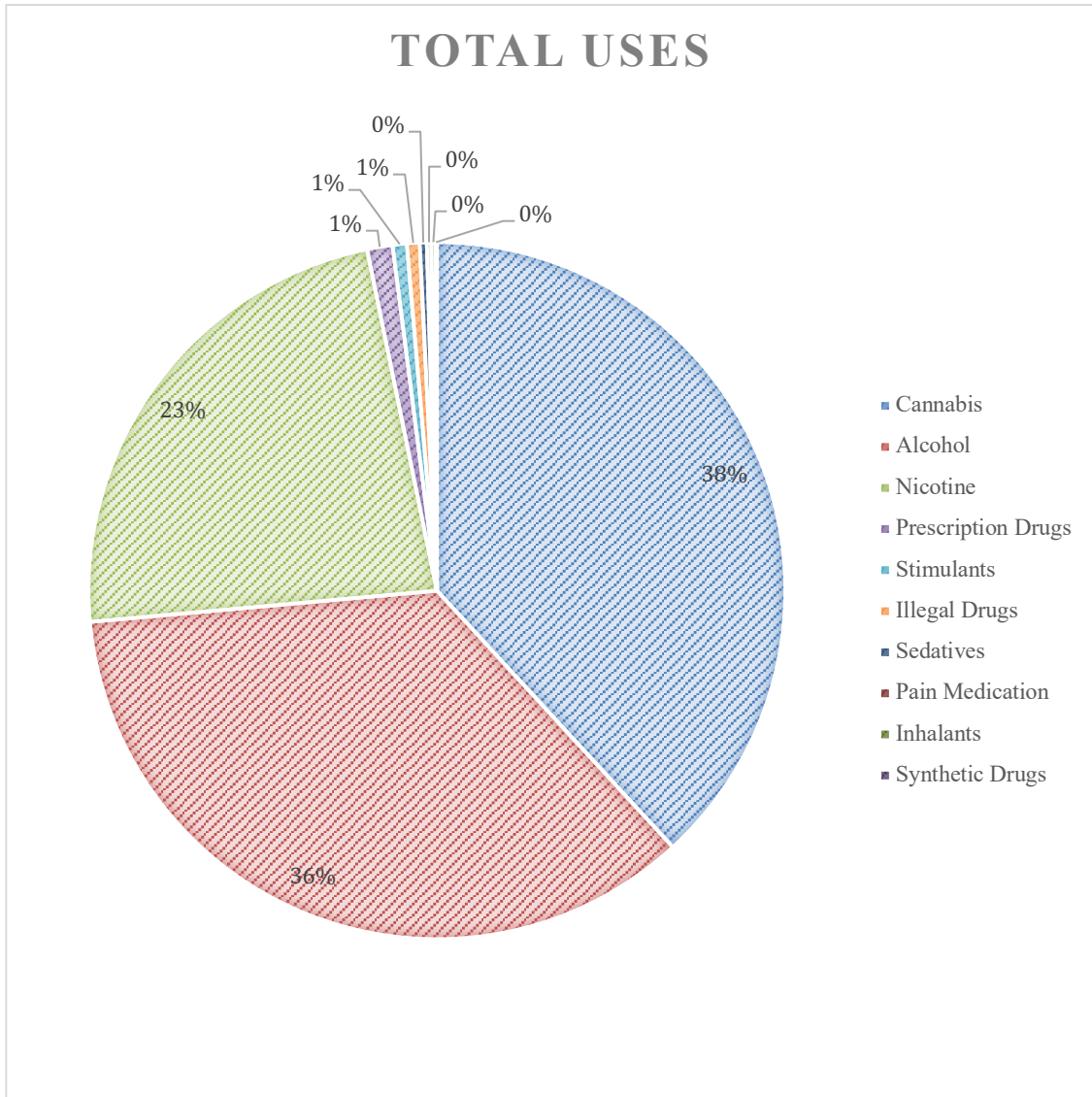


Figure 14: The total uses of each substance shown in a percentage breakdown

Social Media Usage	% of Days

No Usage	8.38%
<1 Hours	10.06%
1-3 Hours	34.75%
3+ Hours	46.81%

Table 6: The table shows the distribution of social media usage on certain days between participants

Social Media Use Reported by Study Participants

Results showed that on almost half of total study days, individuals frequented social media for 3 or more hours (**Table 6, Figure 15**)

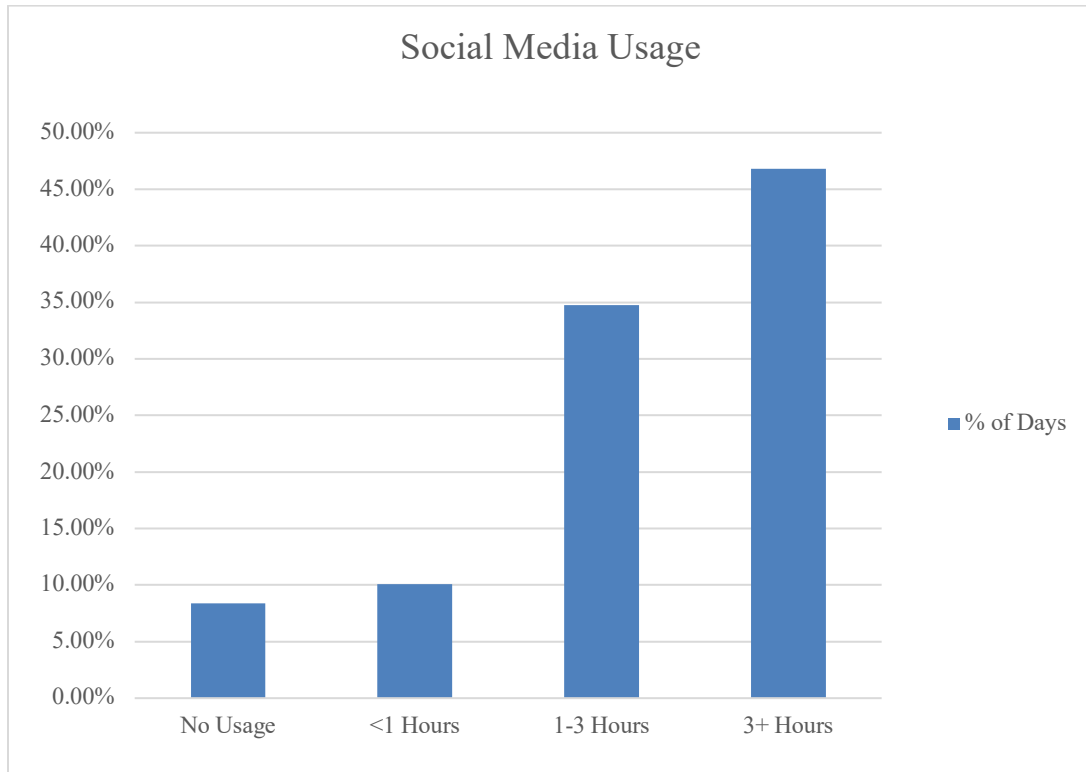


Figure 15: Graph of social media usage reported by participants

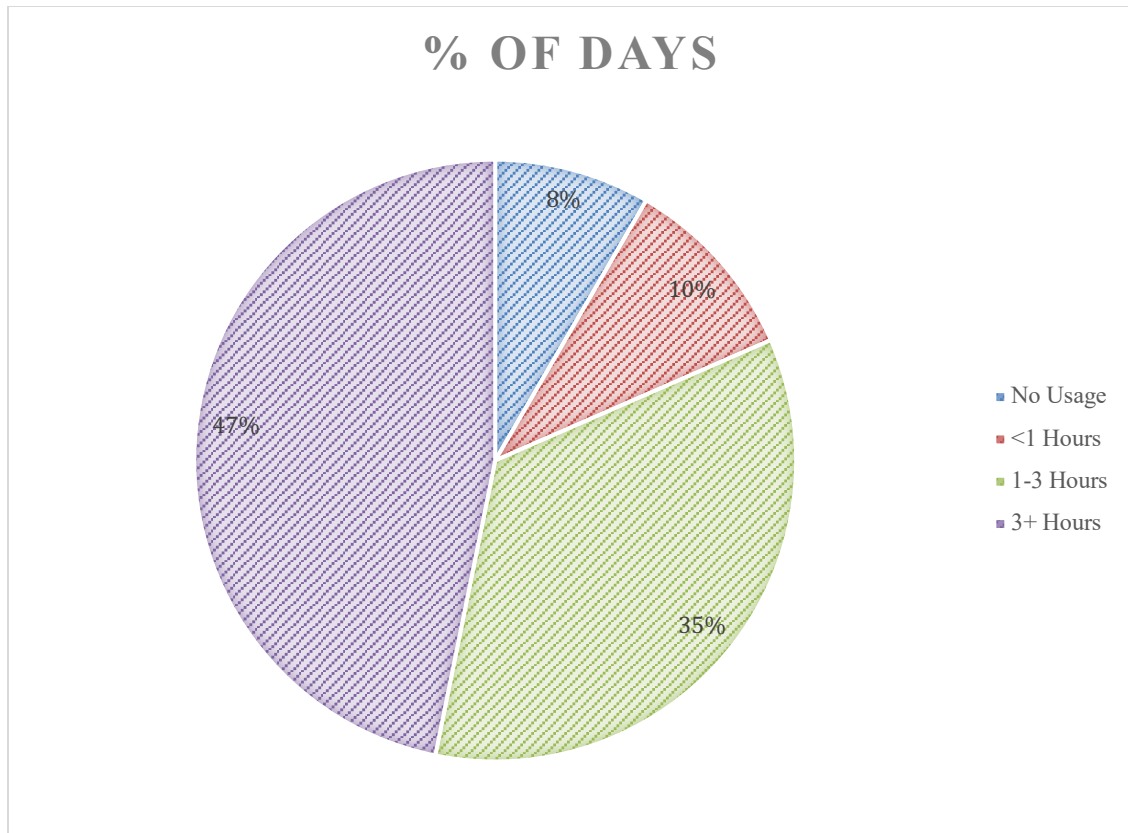


Figure 16: A Pie Chart is shown to visualize social media usage

Discussion

This study expands on findings from Gansner et al. 2024, which also used smartphone-based EMA to examine the temporal relationships between drug-related content exposure and instances of substance use (Gansner, 2024). Consistent with their findings, this study also shows a significant association between substance-related online exposures and same-day substance use. The study showed that the applications that were most used were Instagram, TikTok, and Snapchat respectively (Gansner, 2024). Similarly, in this study Instagram, TikTok, and Snapchat was found to be used the most among participants. The 2024 Study also found that individuals were more likely to encounter peer-posted drug-related content online when TikTok and Snapchat were used the most during a particular day (Gansner, 2014). The relationships between substance use and online drug-related exposures is shown in **Table 7** below. This was a key part in the current study to see if there were any connections between seeing content from a common, known individual and procurement.

Relationships between substance use and online drug-related exposures^a.

Category of online exposure	OR	95% CI		<i>p</i> ^b
		Lower	Upper	
Any exposure	5.37	0.38	75.6	.21
Intentional exposure	6.10	0.82	45.7	.08
Peer-mediated exposure	19.6	1.22	314.8	*.04

Table 7: Relationships between substance use and online drug-related exposures from the Pilot Study Obtained from Ganser et al. 2024

The pilot study found that participants had higher odds of substance use on days in which they saw their peers posting about drugs and alcohol online (Gansner, 2024). The current study was able to show that there was no significant relationship between drug procurement and exposures that were seen on social and digital medias.

Novel findings added by this study include a significant relationship between the total number of substance-related exposures on a particular day and instances of substance use, no relationship between substance-related online exposures and substance use on the following day or substance procurement.

Substance-Related Exposures and Instances of Substance Use

Our findings confirm those seen in prior research suggesting that online exposures to drug-related content are likely to influence substance use (Cabrera-Nguyen, 2016), but the lack of a relationship between prior-day exposure and substance use suggests that this influence is ephemeral in nature. These results are also consistent with prior research suggesting that many acts of substance use are impulsive in nature. Impulsivity can be defined as the tendency to act on urges or desires without forethought or consideration of potential consequences (Kozak, 2019) and impulsivity is considered to key factor to the development of substance use disorders (Wassermen, 2021).

These results could have important implications for high-risk youth with a history of problematic substance use. If youth are able to recognize that they are in a particularly vulnerable state when they are susceptible to drug or alcohol-related cravings, there may be significant benefit in their avoiding recreational digital media use (e.g. scrolling through social media platforms) during those challenging periods.

The significant relationship found between total amount of substance-related exposures and substance use suggests that the influence of these exposures may depend on their quantity. If a particular social media algorithm repeatedly recommends drug-related stories or videos, then use of that platform may be more likely to influence substance use. From a public health standpoint, this could mean that adolescents who engage online with various subcultures that may only be peripherally related to drug use could also be at risk. For example, youth following a musician online who is known to have many cannabis-using fans may be shown cannabis-related online content more regularly as a result of their interest in that artist. not just about that many interested audience with with a peripherdo have undercurrents of substance use.

Substance-Related Exposures and Substance Procurement of Substances

Whether any temporal relationship exists between online exposure to substance-related content and substance procurement is still unclear. It may be that the majority of youth still use substances predominantly in social situations where they had not procured the drugs or alcohol themselves. Potentially, substance-related online exposures may make youth more likely to use drugs or alcohol if they readily available, but not

necessarily seek out and buy them. When offering guidance to adolescents who have substance use issues, clinicians might advise them to avoid situations where they may be offered/exposed to substances in real life if they had recently been watching videos online related to substance use.

Limitations

This study has several limitations that need to be considered when interpreting the findings. Out of our participants, 60.3% identified as white non-Hispanic/Latine, and 75.8% as female. Given rising rates of substance use in racial/ethnic-minority populations, future studies should consider focusing on recruitment of a diverse sample. Additionally, our study cohort was only 62 individuals, although the repeated measurements obtained throughout a 90-day period helps to make up for the smaller sample size (as hundreds of substance use incidents were still able to be captured). Also, while the study recruited nationally, the majority of participants were still recruited from a single geographic region with lower criminalization of illicit drug use and legalized cannabis use. The study produced a population that was heavily populated from the northeastern region of the United States. Since 2021, 36 states have legalized marijuana for medical use, with 18 of these 36 states legalizing marijuana for recreational uses as well (Tolan, 2022). There may be a difference in online drug-related exposures and means of substance use procurement in states where recreational marijuana use is legal and illicit substance use less criminalized. If there are considerations for an international study, this could lead a more robust data set due to various cultural differences that exist.

Future studies should also explore whether the strength of the relationship of substance-related exposures and procurement fluctuates dependent upon the specific types of substance-related exposures. For example, this can range from social media compared to websites, videos or text-based. Seeing the how the relationships is affected by these different mediums will be a good aspect to analyze. Furthermore, to analyze how symptoms of generalized anxiety disorder and depression play a role in this temporal relationship would be valuable

Finally, while the methodology of this study greatly improves upon cross-sectional studies, or even EMA studies where participants are only sampled monthly, daily surveys still cannot exactly delineate whether a substance-use event was before or after an exposure. That level of granularity might be challenging to ascertain from an EMA study, and that degree of precise recall may be challenging for some participants. Qualitative research studies could be helpful in understanding youth cognitions following substance-related online exposures.

Conclusion

The results of this study confirm prior findings of a significant relationship between exposure to substance-related content and same-day substance use, and also suggest that the number of substance-related exposures might exert greater influence. The lack of a significant relationship between instances of substance use and prior-day substance-related exposures is potentially encouraging as it suggests that the influence of substance-related exposures on substance use might be short-lived. Furthermore, the lack

of a relationship between substance procurement and substance-related exposures may also have important implications, as it suggests that youth are not more likely to purchase substances online after visualizing drug-related online content. However, future studies should explore whether the strength of this relationship varies dependent upon specific types of substance-related exposures (e.g. video vs. text-based, social media vs. website).

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