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The psychosocial predictors and day-level correlates of substance use among participants recruited via an online crowdsourcing platform in the United States

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Abstract: 441/450

Background: Alcohol and stimulant use are major public health problems and contribute to a substantial amount of morbidity and mortality in the United States (US). To inform interventions for substance use, there is a need to identify the day-level correlates of substance use by collecting repeated measures data in one's natural environment. There is also a need to use crowdsourcing platforms like Amazon Mechanical Turk (MTurk) to efficiently recruit larger populations of people who use alcohol and stimulants in research.

Objectives: We aimed to 1) utilize daily diaries to examine the temporal relationship between day-level cravings for alcohol and stimulants and substance use (i.e., heavy drinking or any drug use) in a given day over 14 days; and 2) assess whether depression, negative affect and self-esteem measured at baseline predicted substance use in a given day over 14 days among people who use alcohol and or stimulants in the US who were recruited using MTurk.

Methods: Individuals $\geq$ 18 in the US who reported alcohol or stimulant (i.e., cocaine, crack cocaine and methamphetamine) use in the past year, were recruited using MTurk between March 26th and April 13th, 2018. Eligible participants completed a baseline survey and 14 daily surveys online. The baseline survey assessed socio-demographics and psychosocial (i.e., depression, affect, self-esteem and stress) factors. Daily surveys assessed substance use and cravings for alcohol and stimulants. Four multivariable random-intercept logistic regression models were built to examine psychosocial constructs separately along with other significant predictors from bivariate analyses while controlling for age and education.

Results: Among a total of 272 participants, the average age was 36.1 (standard deviation [SD]=10.5), most (80.8%) were White and male (73.9%) and 65.3% were men who reported having sex with other men (MSM). At baseline, 63.8% engaged in any current or past hazardous alcohol consumption, 15.3% reported using cocaine, 10.1% reported using methamphetamine, 4.4% reported using crack cocaine and 38.2% reported any non-injection or injection drug use in

the past six months. Factors independently associated with substance use were depression (adjusted odds ratio [aOR]=1.11, 95% CI=1.02-1.21, *P*=0.01), negative affect (aOR=1.08, 95% CI=1.01-1.16, *P*=0.01), lower levels of self-esteem (aOR=0.90, 95% CI=0.82-0.98, *P*=0.02), and cravings for alcohol (aOR=1.02, 95% CI=1.01-1.03, *P*<0.001) and stimulants (aOR=1.03, 95% CI=1.01-1.04, *P*=0.01). Lastly, MSM had a higher odds of engaging in substance use in all models: (aOR=4.90, 95% CI=1.28-18.70, *P* =0.02); (aOR=5.47, 95% CI=1.43-20.87, *P* =0.01); (aOR=5.99, 95% CI=1.55-23.13, *P* =0.009) and (aOR=4.94, 95% CI=1.29-18.84, *P* =0.01).

Conclusions: Interventions for substance use should utilize evidenced-based approaches to reduce depression, negative affect and cravings, increase self-esteem and engage MSM. Interventions may also consider leveraging technology-based interventions to reduce substance use among populations who use crowdsourcing platforms.

Introduction

Drug and alcohol use are major public health problems and contribute to a substantial amount of morbidity and mortality among adults in the United States (US) [1–3]. Psychosocial stressors and biobehavioral features both play key roles in drug and alcohol use behaviors [4–6]. For instance, depression [7], negative affect (e.g., guilt or shame) [8,9] stress [10,11] and low self-esteem [12,13] are known to characterize patterns of substance use. Further, craving which can be described as an urge or desire to use drugs or alcohol, is a key biobehavioral aspect of substance use disorder (SUD) [6,14] and has been linked to drug and alcohol use in several studies [6,15,16]. However, understanding how these psychosocial factors and biobehavioral features influence substance use on a day-to-day basis remains understudied, especially among populations who use crowdsourcing platforms.

The relationship between craving and substance use is difficult to measure with accuracy because of the transient nature of craving [17]. Further, substance use can be episodic and is often shaped by mood and context (e.g., social setting) [18]. Therefore, in order to more accurately capture the daily patterns associated with substance use methodological approaches that overcome these challenges should be leveraged. The daily dairy method [18–20] offers a promising opportunity to identify the day-level correlates of substance use by collecting repeated measures over time in one's natural environment thereby taking into account within person variation related to mood and context [17,18,21].

Substance use research generally relies on traditional recruitment methods (e.g., targeted sampling or respondent driven sampling), which are expensive and time consuming [22,23]. Also, people who use alcohol or other drugs are often difficult to retain in research which can result in small sample sizes and limited generalizability [23]. Amazon Mechanical Turk (MTurk) is an innovative crowdsourcing platform that can be used to overcome these limitations by efficiently recruiting and engaging larger populations of people who use alcohol or other drugs in research using the internet [23]. Although MTurk has been used more widely over the past decade, it is still underutilized, and its use may improve the scientific rigor of substance use

research by overcoming the limitations noted above. In addition, MTurk may reduce underreporting bias by enabling participants to report on sensitive behaviors in private settings [23]. More research which leverages MTurk and the daily diary method together is needed to engage larger populations of people who use alcohol or other drugs in research and to identify the day-level correlates of substance use. This may advance our understanding of the public health program needs related to substance use for populations who use crowdsourcing platforms in the US.

In order to reduce this gap in research, we utilized daily dairies to identify the day-level correlates of substance use in a given day over a two-week follow-up period among people who use alcohol and or stimulants who were recruited using MTurk in the US. In addition, we assessed the relationship between key psychological factors measured at baseline and substance use in a given day over the two-week follow-up period. More specifically, the main two objectives of this study were to: 1) examine the relationship between day-level cravings for alcohol or stimulants (i.e., crack cocaine, cocaine, or methamphetamine) and substance use in a given day, and 2) determine whether certain psychosocial factors such as depression, negative affect, self-esteem and stress measured at baseline were associated with substance use in a given day over the follow-up period. We hypothesized that both day-level cravings for alcohol and stimulants and psychosocial stressors would be key predictors of substance use among MTurk users. Taken together, this research aims to identify the daily correlates and baseline predictors of substance use among people who use alcohol and or stimulants who were recruited using MTurk, which may help inform the development of interventions for populations who utilize crowdsourcing platforms in the US.

Methods

Ethical considerations. Baseline and follow-up data were drawn from the Stimulants and Alcohol use in MTurk Behavioral Assessments Study (SAMBA), a study designed to examine substance use and HIV-related sexual risk behaviors among men who have sex with men (MSM) and non-MSM who use alcohol and or stimulants in the US. All study procedures and materials were reviewed and approved by the Institutional Review Board at the University of California,

San Francisco. All participants provided informed consent using an online consent form during the screening process.

Recruitment, screening and enrollment. A total of 272 participants in the US were enrolled using MTurk between March 26th and April 13th, 2018. Participants were recruited online using MTurk [23] which involved posting an initial "Human Intelligence Task" (HIT) and then screening participants for eligibility. Participants were considered eligible if they were: 1) at least 18 years old, 2) able to speak English and 3) reported alcohol or stimulant (i.e., cocaine, crack cocaine, or methamphetamine) use in the past year at baseline. The SAMBA Study recruited 1:1 for each of the two eligible groups: MSM who use alcohol or stimulants and non-MSM who use alcohol or stimulants. The parent study was interested in examining both substance use and HIV-related risk behaviors and explicitly sampled MSM because this population is disproportionately impacted by both substance use and HIV-related risk behaviors [24,25].

Online Surveys. All surveys were administered online and completed using computers or smartphones. First, participants completed an initial survey to be screened for eligibility and if they were considered eligible, they completed a baseline assessment followed by 14 daily surveys. Participants were compensated $0.80 for completing the screener, $5.00 for completing the baseline survey, $1.00 for the completion of each daily diary and those who completed all 14 daily surveys received a $6.00 bonus, resulting in a maximum $25.80 in compensation per participant. Research staff contacted participants through their individual MTurk accounts and provided a link to complete the assessments using a unique authenticator known as a single sign on token.

Baseline Measures

Socio-demographics. We assessed socio-demographic factors including age in years and race/ethnicity (White, Asian, African American/Black, Native American/Alaskan Native, and Hawaiian/Pacific Islander). Being a sexual minority male (i.e., MSM), was assessed using a dichotomous measure created from the responses to the following questions: 1)*"What was your sex at birth (male/female)?"* and 2) *"Who do you have sex with (men/women/transgender*

females or transwomen/transgender males or transmen)?" Data were also collected on; relationship status (married/committed, single and divorced), employment status (full time, part time and unemployed), having health insurance (yes/no), ever testing for HIV (yes/no) and annual income (≥ $125,000, $75,000-$124,999, $40,000-$74,999 and ≤ $40,000). Having at least a four-year degree was assessed by creating a dichotomous variable that included those who attained a bachelor's degree or completed any postgraduate studies, versus those who completed 12th grade/general education degree or an associate of arts degree/some college.

     Alcohol use. We measured alcohol consumption in the past six months (yes/no) and current or past hazardous drinking (yes/no) using the 3-item AUDIT-C where scores ≥ 4 for males and ≥ 3 for females indicate hazardous drinking [26,27]. The AUDIT-C consists of three questions that are designed to help identify problematic alcohol use and scores range from 0-12 (a score of 0 reflects no alcohol use in the past year) [26,27]. Higher AUDIT-C scores represent a higher likelihood that the participants drinking is negatively affecting their health [26,27].

     Drug use. Methamphetamine use, cocaine use, crack cocaine use and any drug use which included reporting any injection or non-injection drug use in the past six months (yes/no) were also assessed.

Psychosocial Measures at Baseline

     Self-esteem was assessed using the 10-item Rosenberg Self-Esteem Scale (RSES) [28,29], where higher scores represent higher levels of self-esteem (alpha=0.92). Participants recorded their level of agreement with statements assessing general feelings related to esteem on a 4-point scale ranging from "strongly agree" to "strongly disagree". Items 2, 5, 6, 8, and 9 were reverse coded to ensure that higher scores represent higher levels of self-esteem. Final scores were assessed by summing the scores from all ten items.

     Positive and negative affect were measured using the 20-item Positive and Negative Affect Schedule (PANAS) [30], where scores range from 10-50 and higher scores indicate higher levels of positive (alpha=0.90) or negative (alpha=0.94) affect. Using a 5-point scale (1=very slightly or not at all to 5=extremely) participants recorded their level of agreement with the 20 emotions assessed on the PANAS. Positive affect was measured by summing scores from items:

1, 3, 5, 9, 10, 12, 14, 16, 17 and 19. Negative affect was measured by summing scores from items 2, 4, 6, 7, 8, 11, 13, 15, 18 and 20.

Stress was measured using the 10-item Perceived Stress Scale (PSS) [31], where scores range from 0-40 and higher scores represent higher levels of perceived stress. Using a 5-point scale (0=never to 4=very often) participants reported how often they experienced different feelings and thoughts in the past month. Items 4, 5, 7 and 8 were reverse coded to ensure that higher scores represent higher levels of stress. All items were summed to calculate total stress scores. For descriptive purposes low stress (scores range from: 0-13), moderate stress (scores range from 14-26) and high stress (scores range from 27-40) were also measured using the PSS.

Depression was measured using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D-10) [32] where scores range from 0-30 and scores ≥ 10 are considered depressed (alpha=0.91). Using a 4-point scale (0=rarely or none of the time/less than one day to 3=all of the time/5 to 7 days) participants reported how often in the past week they experienced different emotional states. Item 10 *("I could not get going")* was not included in the survey in error, so scoring for this item was calculated by taking the average scores from items 1-9. Items 5 and 8 were reverse coded to ensure that higher scores represent higher levels of depression. All 10-items were summed to calculate total depression scores.

Daily Diary Measures

Outcome. Our outcome of interest was a dichotomous measure of substance use in a given day that was created by combining heavy drinking and any drug use in the past 24 hours (yes/no). This measure included all individuals who reported heavy drinking or any drug use in the past 24 hours over the 14-day follow-up period (not at baseline). Heavy drinking in the past 24 hours (yes/no), was a dichotomous measure defined according to the National Institute on Alcohol Abuse and Alcoholism's guidelines which states that six or more drinks for males and five or more drinks for females per day is considered heavy drinking [33]. Any drug use (including any injection and non-injection drug use) in the past 24 hours (yes/no), was a dichotomous measure derived from the following two questions: *"In the past 24 hours, have you used any non-injection drugs recreationally or to get high (e.g., crystal meth/speed, crack or powder cocaine, marijuana, heroin, GHB, prescription medications such as Oxycontin or Xanax,*

hallucinogens such as LSD, or others)?" and *"Have you injected any drug in the past 24 hours?"* All data for the outcome were collected post baseline via 14 daily diaries.

Cravings for alcohol and stimulants. In addition to alcohol and drug use, participants were asked to report their day-level cravings for alcohol and or stimulants (i.e., cocaine, crack cocaine and methamphetamine) in the past 24 hours as appropriate. Craving scales ranged from 0-100, where100 represents the strongest craving one has ever experienced and 0 represents is no craving at all. Data on cravings were collected post baseline via 14 daily diaries.

Statistical Analysis

Descriptive statistics were used to describe the study sample. For categorical variables frequencies and percentages were used and depending on distributional assumptions for continuous data (i.e., normal distribution versus non-normal distribution), means and standard deviations (SD) or medians and interquartile ranges (IQR) were used.

Logistic mixed effects regression models were used to analyze the associations between substance use and both time-invariant and time-varying factors over 14 days. Time-varying covariates were measured via 14 daily surveys and assessed day-level cravings for alcohol and stimulants (i.e., cocaine, crack cocaine and methamphetamine). All models included a random intercept to account for repeated measures per person [34]. Measurements at timepoints for which there were no missing outcome or covariate information were included in the model (there was a small amount of missing data and this pattern is summarized below) [34].

We first fit bivariate models to test each factor on substance use individually (a conservative Bonferroni multiple comparison correction for 24 tests would be *P*<.002). For those factors that were significantly (*P*<.051) associated with substance use we then fit multivariable models to determine if they independently contributed to substance use. Multivariable models controlled for age and education because they have been identified as correlates of substance use in prior research [35,36]. Due to the high level of correlation between the psychosocial measures (depression, affect, self-esteem and stress) we examined, they were fit in four separate models which also included the other exposures that were significant in bivariate analyses. A manual backwards selection approach [37] that considered multicollinearity between all exposures was used to build all four final models. Variables that did not retain a *P* value that was <.051 were

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removed from the final models in order to achieve parsimony and enhance the fit of each model. A main effect of time over the follow-up was explored in each of the four models using an indicator variable for day of follow-up but was not significant in any of the models and therefore not included in the final analyses.

For all longitudinal data including the outcome substance use in a given day and cravings for alcohol and stimulants in the past 24 hours, the overall percentage of missing data was calculated by summing the total number of missing responses and then dividing that number by the total number of potential responses (272*14=3,808). The overall percentage of surveys completed was calculated by summing the number of surveys completed and dividing that number by the total number of surveys (3,808). The average number of surveys completed per person was calculated by dividing the total number of completed surveys by the total sample size. All analyses were conducted using Stata 14.2.

Results

A total of 3,897 individuals responded to the MTurk task posted for this study. Of these, 2,910 were screened out because they did not meet the eligibility criteria and another 41 were not included because they did not complete the screening survey. Of the 946 who were considered eligible according to screening data, 161 were MSM and 785 were non-MSM. Of the 161 eligible MSM 152 agreed to participate and of the 785 eligible non-MSM 781 agreed to participate resulting in a total of 13 who declined or opted out. However, this study only had the capacity to enroll 272 participants and had to waitlist the remaining 661. All of the participants who were enrolled were consented at baseline. Completion rates for the 14 daily surveys were: day 1 (99.26%); day 2 (98.16%); day 3 (99.26%); day 4 (95.95%); day 5 (94.11%); day 6, (91.91%); day 7 (95.95%); day 8 (95.22%); day 9 (95.95%); day 10 (94.85%); day 11 (92.64%); day 12 (90.80%); day 13 (92.27%) and day 14 (89.70%).

Baseline characteristics of the study sample are described in Table 1. Among a total of 272 participants 73.9% were male and 65.3% were MSM. The mean age was 36.1 (SD=10.5), and the majority of the sample identified as being White (80.8%), followed by African American/Black (8.0%), Asian (6.2%), Other (3.6%) and Native American or Alaskan Native (1.1%). Most participants were married or in a committed relationship (58.0%), less than half of

the sample reported being single (41.1%) and only 0.7% were divorced. Most participants (66.1%) reported being fully employed and over half (59.9%) reported having at least a four-year degree. Annual income varied with slightly over a third (36.4%) earning ≤ $40,000, 32.7% earning between $40,000-$74,999, 23.5% earning between $75,000-$124,999 and 7.3% earning ≥ $125,000. The majority (84.1%) of the sample reported having health insurance and over half (62.5%) reported ever being tested for HIV.

Nearly all (99.2%) participants reported consuming alcohol in the past six months, the mean AUDIT-C score for any current or past drinking was 4.2 (SD=2.4) and 63.8% engaged in any current or past hazardous alcohol consumption. In the past six months, 15.3% reported using cocaine, 10.1% reported using methamphetamine, 4.4% reported using crack cocaine and 38.2% reported any non-injection or injection drug use. On a scale from 0-100 median day-level cravings at baseline for alcohol, methamphetamine, cocaine and crack cocaine were 5 (IQR=0-26), 54 (IQR=20-88), 39 (IQR=1-71) and 52 (IQR=51-87), respectively.

The median score for self-esteem was 30 (IQR=26-35). On a scale from 10-50 median scores for positive and negative affect were 31 (IQR=26-37) and 15 (11-20), respectively. On a scale from 0-40 the median perceived stress score was 17 (IQR=11-21) and just over half (55.8%) of the sample reported experiencing moderate stress, followed by low stress (34.1%) and then high stress (9.9%). On a scale from 0-30 where a score ≥ 10 is considered depressed, the median score for depression was 7.7 (IQR=3.3-12.2).

Missing data. Overall, there was a minimal amount of missing data. The percentage of missing responses for the primary outcome (substance use in the past 24 hours over the follow-up period) was 4.5%. The rate of missing responses for day-level cravings for alcohol in the past 24 hours was 5.2%. The amount of missing responses for day-level cravings for cocaine, crack cocaine and methamphetamine in the past 24 hours was 6.6% for each measure of craving.

Table 1. Baseline sociodemographic characteristics, psychosocial factors and substance use among people who use alcohol and or stimulants recruited via MTurk between March 26th and April 13th, 2018 in the United States (N=272)	
	n (%)

Sociodemographic factors	
Mean age (standard deviation=SD)	36.10 (10.4)
Race/ethnicity	
White	220 (80.8)
Asian	17 (6.2)
African American	22 (8.0)
Native American or Alaskan Native	3 (1.1)
Other	10 (3.6)
Gender/self-reported sex	
Male	201 (73.9)
Female	71 (26.1)
Men reporting sex with other men_1	134 (65.3)
Relationship status	
Single	112 (41.1)
Married/committed	158 (58.0)
Divorced	2 (0.7)
Employment status	
Full time employment	180 (66.1)
Part time employment	45 (16.5)
Unemployed	47 (17.2)
Higher education (bachelor's degree/any postgraduate studies)	163 (59.9)
Income	
≥ $125,000 (reference)	20 (7.3)
$75,000-$124,999	64 (23.5)
$40,000-$74,999	89 (32.7)
≤ $40,000	99 (36.4)
Has health insurance	229 (84.1)
Reported ever testing for HIV	
Yes	170 (62.5)
No	95 (34.9)
Don't know	7 (2.5)
Substance use	
Alcohol consumption in the past six months	261 (99.2)
Mean Audit-C score (SD)_2	4.2 (2.4)
Hazardous alcohol consumption_3	173 (63.8)
Methamphetamine use in the past six months	19 (10.1)
Cocaine use in the past six months	31 (15.3)
Crack cocaine use in the past six months	8 (4.4)

Any drug use in the past six months including injection drug use	104 (38.2)
Substance use cravings_4	
Median day-level craving for alcohol in the past 24 hours (interquartile range=IQR)	5 (0-26)
Median day-level craving for methamphetamine in the past 24 hours (IQR)	54 (20-88)
Median day-level craving for cocaine in the past 24 hours (IQR)	39 (1-71)
Median day-level craving for crack cocaine in the past 24 hours (IQR)	52 (51-87)
Psychosocial factors	
Median self-esteem score (IQR)_5	30 (26-35)
Affect_6	
Median positive affect (IQR)	31 (26-37)
Median negative affect (IQR)	15 (11-20)
Median perceived stress score (IQR)_7	17 (11-21)
Low stress	93 (34.1)
Moderate stress	152 (55.8)
High stress	27 (9.9)
Median depression score ($\geq$ 10 is considered depressed) (IQR)_8	7.7 (3.3-12.2)

Notes:
1_MSM=males who reported having sex with other males
2_AUDIT-C scores were calculated using the 3-item AUDIT-C
3_Hazardous drinking was measured at baseline using the 3-item AUDIT-C. Scores range from 0-12, scores of 4 or more for men indicate hazardous drinking and scores of 3 or more for women indicate hazardous drinking.
4_Day-level cravings range from 0-100
5_Self-esteem was measured using the 'Rosenberg Self-Esteem Scale' (RSES), higher scores represent higher self-esteem
6_Affect was measured using the 'Positive and Negative Affect Schedule' (PANAS). Scores range from 10-50, with higher scores indicating higher levels of positive or negative affect. Positive and negative affect were measured by summing different items from the PANAS scale.
7_Stress was measured using the 'Perceived Stress Scale' (PSS). Scores range from 0-40 with higher scores representing higher perceived stress. Scores ranging from 0-13 are considered low stress, 14-26 are considered moderate stress, and 27-40 are considered high stress.
8_Depression was measured using the 10-item Center for Epidemiologic Studies Depression Scale Revised (CESD-10). A score equal to or above 10 is considered depressed.

Bivariate analyses. Results from bivariate logistic regression models examining predictors of substance use in a given day measured at baseline and each day over the follow-up period are summarized in Table 2, in addition to descriptive data stratified by substance use on day 1. Part time employment was associated with a higher odds of substance use in a given day over the follow-up compared to those who were fully employed. Those who had a bachelor's degree or completed some postgraduate work had a significantly lower odds of engaging in substance use in a given day over the follow-up period compared to those who reported

completing less education. Those who earned <$40,000 annually had a higher odds of substance use in a given day compared to those who earned >$125,000 annually. MSM had a significantly higher odds of substance use in a given day compared to those who were not MSM.

Every one-point increase in self-esteem was associated with a significantly lower odds of engaging in substance use in a given day. Every one-point increase in negative affect was associated with a significantly higher odds of engaging in substance use in a given day. Similarly, increases in perceived stress and depression were associated with significantly higher odds of engaging in substance use in a given day. Higher day-level craving scores in the past 24 hours for alcohol, cocaine, crack cocaine and methamphetamine were all significantly associated with a higher odds of engaging in substance use in a given day over the follow-up period.

Table 2. Bivariate random-intercept logistic regression models of predictors of substance use in a given day among people who use alcohol and or stimulants recruited via MTurk between March 26th and April 13th, 2018 in the United States (N=272)				
Variable	Substance use in the past 24 hours on day 1 n=50	No substance use in the past 24 hours on day 1 n=220	Unadjusted Odds Ratio (95% CI)	*P*
Sociodemographic factors at baseline+				
Mean age (SD)	35.50 (10.44)	36.32 (10.34)	0.99 (0.94-1.03)	.66
Race/ethnicity				
White (reference)	40 (80.00)	178 (80.91)		
Asian	1 (2.00)	16 (7.27)	0.19 (0.26-1.40)	.10
African American	5 (10.00)	17 (7.73)	3.61 (0.62-21.05)	.15
Native American or Alaskan Native	1 (2.00)	2 (0.91)	13.61 (0.10-1726.21)	.29
Hawaiian or Pacific Islander	3 (6.00)	7 (3.18)	3.57 (0.28-44.84)	.32
Relationship status				
Married/committed (reference)	28 (56.00)	128 (58.18)		
Single	22 (44.00)	90 (40.91)	1.53 (0.59-3.96)	.37
Divorced	--	2 (0.91)	--	--
Employment status				
Full time employment (reference)	31 (62.00)	149 (67.73)		
Part time employment	13 (26.00)	32 (14.55)	5.70 (1.54-21.00)	.009
Unemployed	6 (12.00)	39 (17.73)	0.63 (0.18-2.18)	.46
Higher education (bachelor's degree or any postgraduate)	24 (48.00)	138 (62.73)	0.23 (0.08-0.59)	.003
Income				

≥ $125,000 (reference)	4 (8.00)	16 (7.27)		
$75,000-$124,999	3 (6.00)	61 (27.73)	0.39 (0.05-2.67)	.33
$40,000-$74,999	14 (28.00)	75 (34.09)	1.03 (0.16-6.53)	.97
≤ $40,000	29 (58.00)	68 (30.91)	6.84 (1.09-42.81)	.04
Has health insurance	42 (84.00)	185 (84.09)	0.44 (0.12-1.64)	.22
Ever tested for HIV	36 (72.00)	132 (60.00)	0.69 (0.46-1.04)	.07
Men reporting sex with other men_1	37 (82.22)	96 (60.76)	7.35 (2.40-22.56)	<.001
Substance use cravings at day one^_2				
Median Day-level craving for alcohol in the past 24 hours (IQR)	10.5 (0-50)	3 (0-15)	1.03 (1.02-1.04)	<.001
Median Day-level craving for methamphetamine in the past 24 hours (IQR)	0 (0-9)	0 (0-0)	1.03 (1.01-1.05)	<.001
Media Day-level craving for cocaine in the past 24 hours (IQR)	0 (0-1)	0 (0-0)	1.04 (1.02-1.06)	<.001
Median Day-level craving for crack cocaine in the past 24 hours (IQR)	0 (0-0)	0 (0-0)	1.04 (1.02-1.06)	<.001
Psychosocial factors at baseline+				
Median self-esteem score (IQR)_3	27.5 (23-32)	30 (27-36)	0.87 (0.81-0.93)	<.001
Median positive affect score (IQR)_4	30 (25-34)	32 (26-38)	0.94 (0.89-1.00)	.07
Median negative affect score (IQR)_4	19.5 (15-32)	14 (11-18.5)	1.14 (1.08-1.21)	<.001
Median perceived stress score (IQR)_5	20 (15-23)	16 (10-20)	1.13 (1.06-1.20)	<.001
Median depression score (a score ≥ 10 is depressed) (IQR)_6	11.66 (4.44-17.77)	6.66 (2.22-12.22)	1.19 (1.11-1.27)	<.001

Notes:

Time invariant covariates measured at baseline+

Time varying covariates measured at day one over the follow-up period^

P-values were derived from random effects logistic regression

1_MSM=males who reported having sex with other males

2_Day-level cravings in the past 24 hours were assessed on a scale ranging from 0-100, where 0 is no craving at all and 100 is the strongest craving one has ever experienced

3_Self-esteem was measured using the 'Rosenberg Self-Esteem Scale' (RSES), higher scores represent higher self-esteem

4_Affect was measured using the 'Positive and Negative Affect Schedule' (PANAS). Scores range from 10-50, with higher scores indicating higher levels of positive or negative affect. Positive and negative affect were measured by summing different items from the PANAS scale.

5_Stress was measured using the 'Perceived Stress Scale' (PSS). Scores range from 0-40 with higher scores representing higher perceived stress. Scores ranging from 0-13 are considered low stress, 14-26 are considered moderate stress, and 27-40 are considered high stress.

6_Depression was measured using the 10-item Center for Epidemiologic Studies Depression Scale Revised (CESD-10). A score equal to or above 10 is considered depressed.

In the bivariate logistic regression models, substance is the outcome and is a composite variable that includes those who reported heavy drinking and or any drug use in the past 24 hours over a two-week follow-up period

In columns 2 and 3, substance use is the outcome and includes those who reported heavy drinking and or any drug use in the past 24 hours on day one

Multivariable analyses. Results from all four multivariable logistic regression models examining baseline predictors and daily correlates of substance use in a given day while controlling for age in years and education are summarized in Table 3. In model one, factors significantly associated with substance use in a given day were: self-esteem (aOR=0.90, 95% CI=0.82-0.98, *P*=.02), day-level craving scores for alcohol and cocaine (aOR=1.02, 95% CI=1.01-1.03, *P*<.001; and aOR=1.03, 95% CI=1.01-1.04, *P*=.01), respectively and being an MSM (aOR=4.90, 95% CI=1.28-18.70, *P*=.02). In model two, factors significantly associated with substance use in a given day were negative affect (aOR=1.08, 95% CI=1.01-1.16, *P*=.01), day-level craving scores for alcohol and cocaine (aOR=1.02, 95% CI=1.01-1.03, *P*<.001; and aOR=1.02, 95% CI=1.01-1.04, *P*=.001), respectively and being an MSM (aOR=5.47, 95% CI=1.43-20.87, *P*=.01). In model three, factors that were significantly associated with substance use in a given day were day-level craving scores for alcohol and cocaine (aOR=1.02, 95% CI=1.01-1.03, *P*<.001 and aOR=1.03, 95% CI=1.01-1.04, *P*=.001), respectively and being an MSM (aOR=5.99, 95% CI=1.55-23.13, *P*=.009). In model four, factors significantly associated with substance use in a given day were depression (aOR=1.11, 95% CI=1.02-1.21, *P*=.01), day-level craving scores for alcohol and cocaine (aOR=1.02, 95% CI=1.01-1.03, *P*<.001; and aOR=1.02, 95% CI=1.01-1.04, *P*=.001), respectively and being an MSM (aOR=4.94, 95% CI=1.29-18.84, *P*=.01).

Table 3. Multivariable random-intercept logistic regression models of predictors of substance use in a given day among people who use alcohol and or stimulants recruited via MTurk between March 26th and April 13th, 2018 in the United States (N=272)

Variable	Adjusted Odds Ratio (95% CI) Model 1_a	P	Adjusted Odds Ratio (95% CI) Model 2_b	P	Adjusted Odds Ratio (95% CI) Model 3_c	P	Adjusted Odds Ratio (95% CI) Model 4_d	P
Sociodemographic factors measured at baseline+								
Mean age (SD)	1.01 (0.95-1.07)	.64	1.01 (0.95-1.07)	.62	1.01 (0.95-1.07)	.73	1.00 (0.95-1.06)	.78
Higher education (bachelor's degree/any postgraduate)	0.18 (0.05-0.61)	.006	0.17 (0.05-0.59)	.005	0.17 (0.05-0.60)	.006	0.19 (0.05-0.65)	.009
Men reporting sex with other men_1	4.90 (1.28-18.70)	.02	5.47 (1.43-20.87)	.01	5.99 (1.55-23.13)	.009	4.94 (1.29-18.84)	.01
Substance use day-level cravings measured over the follow-up^_2								
Day-level craving for alcohol in the past 24 hours	1.02 (1.01-1.03)	<.001	1.02 (1.01-1.03)	<.001	1.02 (1.01-1.03)	<.001	1.02 (1.01-1.03)	<.001
Day-level craving for cocaine in the past 24 hours	1.03 (1.01-1.04)	.01	1.02 (1.01-1.04)	.001	1.03 (1.01-1.04)	.001	1.02 (1.01-1.04)	.001
Psychosocial factors measured at baseline+								
Self-esteem score_3	0.90 (0.82-0.98)	.02						
Negative affect score_4			1.08 (1.01-1.16)	.01				
Perceived stress score_5					1.06 (0.98-1.16)	.11		
Depression score (≥ 10 is considered depressed)_6							1.11 (1.02-1.21)	.01

Notes:

All adjusted models (1-4) controlled for age in years and education (e.g., having at least a BA)

a_Total effect of self-esteem on substance use in a given day

b_Total effect of negative affect on substance use in a given day

c_Total effect of perceived stress on substance use in a given day

d_Total effect of depression on substance use in a given day

P-values were derived from random effects logistic regression

1_MSM=males who reported having sex with other males
2_Day-level cravings in the past 24 hours were assessed on a scale ranging from 0-100, where 0 is no craving at all and 100 is the strongest craving one has ever experienced
3_Self-esteem was measured using the 'Rosenberg Self-Esteem Scale' (RSES), higher scores represent higher self-esteem
4_ Negative affect was measured by summing certain items from the PANAS scale.
5_Depression was measured using the 10-item Center for Epidemiologic Studies Depression Scale Revised (CESD-10). A score equal to or above 10 is considered depressed.
Substance use includes those who reported heavy drinking and or any drug use in the past 24 hours over a two-week period

Discussion

This daily diary study measuring the predictors and day-level correlates of substance use in a given day among people who use alcohol and or stimulants in the US who were recruited via MTurk, identified several important findings. Higher day-level craving scores for alcohol and stimulants predicted substance use in a given day over the 14-day follow-up period. Negative affect and depression measured at baseline were both associated with substance use in a given day. We also found that higher levels of self-esteem measured at baseline were associated with a lower odds of engaging in substance use in a given day over the follow-up period. These findings may have important implications for behavioral interventions that aim to reduce day-to-day patterns of heavy drinking and drug use among people who use alcohol and stimulants in the US.

Using the daily dairy method, our study found day-level cravings for alcohol and stimulants to be correlated with substance use in a given day. Our study adds to existing research that supports the link between craving and substance use [15–17] by showing how cravings measured daily in one's natural environment predict substance use among MTurk users in the US. As such, results from this study may help further our understanding of how day-level fluctuations in cravings shape substance use patterns. These findings point to the potential of the daily diary method in identifying high-risk days for substance use via monitoring cravings on a daily basis. This may be a promising opportunity to deploy mobile health (mHealth) or other technology-based interventions to address craving using empirically driven approaches [38]. For example, mHealth platforms where participants can respond to drinking and drug use queries and receive timely feedback on how to avoid using drugs or alcohol have shown promise [39].

Negative affect was independently associated with substance use in a given day over the two-week follow-up period in this study which is consistent with prior research [40–43]. Based on this finding and former work, we recommend that behavioral interventions address negative affect by utilizing strategies to promote emotional regulation by enhancing positive emotion and sensitizing individuals to natural rewards [44]. Future studies should test whether an increase in positive affect leads to an increase in emotional regulation and a decrease in substance use. Further, utilizing technology-based interventions that address substance use in real-time leveraging mobile platforms or computers to deploy interventions may increase accessibility to

efficacious treatments for people with SUD [45]. Technology-based interventions have also proven to be cost-effective and thus a practical option in resource-limited settings [46].

Depression was associated with substance use in a given day in this study. Individuals who experience depression and engage in substance use tend to have worse treatment outcomes for both depression and substance use compared to those who experience one of these conditions alone [47]. Also, depression accelerates the onset of SUD and predicts relapse among people who use drugs [48]. Thus, it is recommended to treat the underlying mechanisms of both depression and substance use using transdiagnostic approaches that integrate treatments for both disorders [47]. For instance, cognitive behavioral therapy, mindfulness mediation and acceptance-based approaches have all shown promise in addressing both depression and substance use [47] and should be considered in future intervention work. Moreover, to best address the needs of populations who use crowdsourcing platforms delivering combined therapies that simultaneously address depression and substance use using technology-based approaches may be beneficial [38,39,49].

Higher levels of self-esteem were associated with a reduced odds of engaging in substance use over the follow-up period in our study. Previous studies have shown that self-esteem is protective against substance and mediated by adaptive coping mechanisms among multiracial youth and college students in the US [12,13]. Our study adds to this literature [12,13] by showing that higher levels of self-esteem are protective against substance use among MTurk recruited adults who use alcohol and stimulants in the US. Based on our findings and prior research [12,13], interventions for substance use should consider leveraging evidenced based techniques such as cognitive behavioral therapy and motivational interviewing to enhance self-esteem and increase adaptive coping skills using technology-based platforms to engage larger populations of MTurk users [46].

MSM had a significantly higher odds of engaging in substance use in a given day over the follow-up period compared to those who were not MSM in our study. Drug and alcohol use are common among MSM and have been linked to chronic stress due to sexual stigma, depression, sexual anxiety, gay community attachment and internalized homophobia [50]. MSM also report using drugs and alcohol to; enhance their sense of belonging, help cope with everyday life stress and increase their sense of pleasure [51]. In order to reduce substance use among MSM it is

imperative to develop culturally appropriate substance use treatment programs [52] that take the underlying drivers of substance use specific to MSM into account [50].

Perceived stress was not independently associated with substance use in a given day in our study. One possible explanation for this is that our baseline measure of stress was not collected close enough to the repeated measures outcome of interest to detect an association. Stress may be a more transient experience that should be captured using repeated measures data. We recommend that future studies leveraging repeated measures deigns collect data on stress closer to the outcome measure of substance use to better understand the potential temporal effect of stress on substance use. Further, since the relationship between stress and substance use has been established in other studies [10,11] we recommend interpreting our finding with caution and continuing to address stress by enhancing adaptive coping mechanisms in interventions for substance use.

Limitations. This study has limitations. We relied on self-reported data of sensitive behaviors such as drug and alcohol use that were collected via daily diaries which may be subject to social desirability bias and recall bias. These biases may threaten the reliability and validity of our findings by dampening the effect or pushing the results toward the null. However, it should be noted that the daily diary method is known to enhance the ecological validity of substance use research by collecting repeated measures over time in one's natural environment [17]. The lack of racial and ethnic diversity in our sample may limit the generalizability of our results to other populations of people who use alcohol and or stimulants. Future MTurk studies should develop strategies to recruit more diverse samples of people who use alcohol and stimulants to broaden the applicability of research findings [53,54]. Aside from MSM, we were not powered to detect any potential relationship between other sexual minority groups including women who have sex and substance use, which may limit the generalizability of our findings to sexual minorities other than MSM. All psychosocial measures were collected at baseline only therefore no time-varying effect can be inferred from the detected associations. Further, the relationship between stress and substance use may not have been detected because stress was not measured close enough to the repeated measures outcome. Item 10 of the CESD-10 *("I could not get going")* was not included in the study survey in error, so scoring for this item was calculated by taking the average scores from items 1-9, which may compromise the validity of this item. Regression analyses were

performed using data for complete cases only (i.e., all cases with missing outcome or covariate data were excluded). Complete case analysis assumes that data are missing completely at random, which means that the cause of missing data is independent of the observed (i.e., the measured outcome of interest) and unobserved (i.e., other unmeasured causes) parameters of interest [34]. Although this is a strong assumption, it should be noted that the largest overall percentage of missing responses was very minimal (6.6%, for day-level cravings for stimulants in the past 24 hours) and approximately meets the rule of thumb for such an analysis [55]. Despite these limitations, this study provides important insights into the predictors and day-level correlates of substance use among people who use alcohol and or stimulants in the US who were recruited via MTurk.

In summary, day-level cravings for alcohol and stimulants, depression, negative affect, and being a MSM predicted substance use and higher levels of self-esteem were protective against substance use in our sample of people who use alcohol and or stimulants. Interventions that target biobehavioral circuitries such as craving, should be investigated in conjunction with programs that are designed to reduce negative psychosocial stressors like depression. Substance use treatment programs may also consider employing cognitive behavioral strategies to enhance self-esteem and improve adaptive coping. Further, culturally tailored approaches should be developed to effectively engage MSM in interventions. Finally, we recommend delivering interventions for substance use using mHealth or other technology-based platforms, in order to increase accessibility to efficacious treatments for people living with SUD in the US.

Conflicts of Interest: The authors have no conflicts of interest.

Abbreviations: Amazon mechanical turk (MTurk) substance use disorder (SUD), men who have sex with men (MSM) and mobile health (mHealth).

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