Depression, Environmental Reward, Coping Motives and Alcohol Consumption During the
COVID-19 Pandemic

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Abstract

Background: Increases in the incidence of psychological distress and alcohol use during the COVID-19 pandemic have been predicted. Environmental reward and self-medication theories suggest that increased distress and greater social/environmental constraints during COVID-19 could result in increases in depression and drinking to cope with negative affect. The current study had two goals: (1) to clarify the presence and direction of changes in alcohol use and related outcomes after the introduction of COVID-19 social distancing requirements, and; (2) to test hypothesized mediation models to explain individual differences in alcohol use during the early weeks of the COVID-19 pandemic. **Methods:** Participants ($n = 1127$) were U.S. residents recruited for participation in an online survey. The survey included questions assessing environmental reward, depression, COVID-19-related distress, drinking motives, and alcohol use outcomes (alcohol use; drinking motives; alcohol demand, and solitary drinking). Outcomes were assessed for two timeframes: the 30 days prior to state-mandated social distancing ('pre-social-distancing'), and the 30 days after the start of state-mandated social distancing ('post-social-distancing'). **Results:** Depression severity, coping motives, and frequency of solitary drinking were significantly greater post-social-distancing relative to pre-social-distancing. Conversely, environmental reward and other drinking motives (social, enhancement, and conformity) were significantly lower post-social distancing compared to pre-social-distancing. Time spent drinking and frequency of binge drinking were greater post-social-distancing compared to pre-social-distancing, whereas typical alcohol quantity/frequency were not significantly different between timeframes. Indices of alcohol demand were variable with regard to change. Mediation analyses suggested a significant indirect effects of reduced environmental reward with drinking quantity/frequency via increased depressive symptoms and coping motives,

and a significant indirect effect of COVID-related distress with alcohol quantity/frequency via coping motives for drinking. **Discussion:** Results provide early evidence regarding the relation of psychological distress with alcohol consumption and coping motives during the early weeks of the COVID-19 pandemic. Moreover, results largely converged with predictions from self-medication and environmental reinforcement theories. Future research will be needed to study prospective associations among these outcomes.

Keywords: COVID-19, SARS-CoV-2, social distancing, alcohol, mental health, stress, depression

Introduction

In the first 6 months of the COVID-19 pandemic, there have been over 8 million confirmed and presumptive cases of the COVID-19 infection globally (Dong et al., 2020). Attempts to curtail the spread of the virus have included localized approaches (e.g., contact tracing, quarantine) and large-scale population directives (e.g., social distancing and shelter-in-place requirements; Tuite et al., 2020). Given the broad socioeconomic and health impacts of the pandemic, increased incidence of psychological distress and mental health disorders are among the anticipated consequences of the COVID-19 pandemic (e.g., Lima et al., 2020; Rehm et al., 2020; Xiang et al., 2020). Past evidence that societal crises (e.g., economic recessions; natural disasters) were followed by increases in mental health and substance use problems (de Geooij et al., 2015), and preliminary evidence of elevated levels of depression and anxiety during the COVID-19 pandemic (e.g., Centers for Disease Control and Prevention, 2020; Ueda et al., 2020; Wang et al., 2020), have led to calls for research to evaluate mental health outcomes during the COVID-19 pandemic.

Initial data are consistent with potential increases in alcohol consumption during the COVID-19 pandemic. For example, increased alcohol sales (e.g., Da et al., 2020), elevated rates of harmful alcohol use in COVID-19 epicenters (e.g., Ahmed et al., 2020), and altered patterns of alcohol consumption (e.g., based on remote breath alcohol concentration data, BACTrack, 2020) have been reported. The Canadian Centre on Substance Use and Addiction (CCSA) reported that approximately 1 in 5 individuals who consume alcohol reported increases in alcohol consumption relative to the period prior to the pandemic, although the majority did not report an increase in alcohol consumption (CCSA, 2020). These findings are consistent with predictions that circumstances surrounding the pandemic may lead to increases in consumption

for some people, but no change or decreases for others (Rehm et al., 2020), making it important to understand factors coinciding with increases in consumption.

Of numerous contextual factors that could increase risk for alcohol use during the pandemic, changes in psychological distress and mental health symptoms are important considerations. The unprecedented consequences of COVID-19, including widespread unemployment and lost income, health-related concerns, and mandated social isolation are likely risk factors for increases in depression and other forms of psychological distress among the general population. Stress and negative affect are primary risk factors for increases in consumption among regular drinkers, and also the most common relapse precipitants among those who have cut down or quit drinking (Sinha, 2001). Increases in negative affect, including the exacerbation of depression symptoms and/or generalized distress in response to challenges surrounding the pandemic, might lead to increases in alcohol consumption. Some anticipate a drastic increase in alcohol relapse among vulnerable populations as a result (Da et al., 2020).

Other contextual factors that might alter patterns of substance use include social and environmental changes. By design, population-based approaches to virus control have imposed significant environmental and contextual constraints for large portions of the population, resulting in widespread changes to daily routines and social interactions. By introducing constraints to daily routines and reducing access to typical sources of social or environmental reinforcement, strict social distancing measures may increase the risk for psychological distress and/or substance use for some individuals. For instance, reductions in access to environmental/social rewards and increases in reward-limiting stimuli (i.e., environmental suppressors) are associated with elevated risk for/severity of depression (e.g., Carvalho and Hopko, 2011; Hopko et al., 2003; Joiner et al., 2002). Additionally, reduced availability of

environmental rewards and reduced access to non-drug related sources of reinforcement are risk factors for heavy alcohol use (Correia et al., 2003). It follows that environmental constraints related to social distancing measures might indirectly result in increased alcohol consumption, by way of increases in depression or psychological distress and/or limited access to typical sources of reinforcement. Perhaps consistent with these predictions, research during the SARS epidemic found that almost one third (31.2%) of individuals quarantined during the SARS epidemic had positive screens for depression (Hawryluck et al., 2004), and among hospital employees, alcohol use disorder symptoms were positively associated with having been quarantined and working in a high-risk location (Wu et al., 2008).

Additional factors influencing drinking context or drinking opportunities could have implications for the incidence of risky alcohol consumption patterns during the COVID-19 pandemic. Solitary drinking (i.e., use of alcohol alone versus in social contexts) is positively associated with greater incidence of alcohol-related problems (Christiansen et al., 2002; Keough et al., 2018). Notably, frequency of solitary drinking (compared to drinking in social contexts) is positively predicted by severity of depressive symptoms (Keough et al., 2015). To the extent that environmental constraints may limit social drinking opportunities and increase depression symptoms, solitary drinking is likely to increase under social distancing conditions. Additionally, changes in drinking contexts (e.g., bar closures) may call for studying alternative indices of alcohol motivation, such as alcohol demand. Alcohol demand curves demonstrate the reinforcing potential of alcohol based on hypothetical resources (e.g., economic) that an individual would allocate to obtain alcohol (Bickel et al., 2000). Greater alcohol demand is associated with alcohol-related problems and alcohol consumption (Kaplan et al., 2018; MacKillop, 2016). Importantly, dynamic changes in demand have been observed in response to stress manipulations

(Owens et al., 2015), suggesting the importance of considering change in demand as an outcome during the COVID-19 pandemic.

Drinking for negative reinforcement reasons (i.e., to reduce negative affect) plays a central role in stress-related alcohol use, and is associated with significantly increased risk for alcohol problems (Kuntsche et al., 2005). According to the Self-Medication Hypothesis (Khantzian, 1997; Hawn et al., 2020a) drinking to cope with negative affect (i.e., coping motives) is a critical mediator between situational increases in negative affect and subsequent increases in alcohol use and associated problems. The self-medication hypothesis has also been used to explain the relationship between depression and alcohol use/problems (reviewed in Turner et al., 2018). Evidence further suggests a mediating role of coping motives in the association of peritraumatic distress and alcohol-related problems (e.g., Hawn et al., 2020b). While coping motives are central to the self-medication hypothesis, other domains of drinking motives include enhancement motives (i.e., drinking to enhance positive mood), social motives (e.g. affiliation with peers) and conformity motives (e.g., peer pressure; Cooper et al., 1995; Grant et al., 2007). Notably, coping motives uniquely predict heavier drinking and related alcohol problems when controlling for other domains (Kuntsche et al., 2005; Merrill et al., 2014).

While motives for alcohol consumption are often studied as static phenomena and assessed at one point in time, some studies suggest that drinking motives are subject to dynamic change (e.g., Cooper et al., 2008; Littlefield et al., 2010). As a consequence of social (e.g., reduced interpersonal contact) and environmental (e.g., closure of public drinking venues) changes associated with the COVID-19 pandemic, changes in specific reasons for drinking are likely to occur, at least for some individuals. For instance, if social distancing requirements

constrain environmental reward, increased psychological distress or depression (e.g., Pappa et al., 2020; Qiu et al., 2020) might result in escalations in coping motives for drinking and ultimately increased alcohol use. Similarly, increased severity of fear and anxiety specifically related to COVID-19 might predict escalations in negative reinforcement drinking, consistent with the self-medication hypothesis and with past research (e.g., Edwards et al., 2014).

Evidence from other public health crises supports these possibilities. Following the 2003 SARS outbreak, Maunder and colleagues (2006) found that maladaptive coping was associated with self-reported increases in alcohol use among health-care workers. Additionally, in hospital employees, endorsement of using alcohol to cope with the SARS outbreak was positively related to alcohol use disorder symptoms (Wu et al., 2008). This research is limited, however, to samples directly impacted by the disease (e.g., healthcare workers, those in quarantine) and there is a paucity of research in general samples. Initial information on changes in psychological distress and related outcomes (e.g., depression, substance use) during the COVID-19 pandemic may be used to direct intervention efforts in this and future public health crises.

The current study had two primary aims. First, following recommendations to study changes in substance use and associated risk factors during the COVID-19 pandemic (Rehm et al., 2020), we aimed to assess self-reported differences in mood, environmental reward, drinking motives, and alcohol consumption in the period immediately preceding widespread social distancing measures, as compared to the period when these measures were in place. In addition to measuring perceived change in quantity/frequency of consumption, other relevant alcohol outcomes (e.g., solitary drinking; alcohol demand) were also assessed. Exploratory analyses also examined whether any of these outcomes differed as a function of self-identified racial group. The second aim was to examine perceived changes in coping motives and depression symptoms

as accounting for the relation between perceived change in environmental reward and psychological distress with alcohol consumption during the COVID-19 pandemic. Based on self-medication theory (Khantzian, 1997) and theories concerning the relation of environmental reward with depression and substance use (e.g., Vuchinich and Tucker, 1983) two primary hypotheses were tested. First, we predicted that individual differences in environmental reward during COVID-19 would predict severity of depressive symptoms, which would in turn predict coping motives and alcohol consumption. Second, we predicted that psychological distress attributed specifically to COVID-19 would predict greater endorsement of coping motives, which would in turn predict greater quantity/frequency of alcohol consumption.

Methods

Participants

Participants were U.S. residents recruited from Amazon's Mechanical Turk (MTurk) between May 12, 2020 and May 23, 2020. A total of 1854 individuals were screened for participation. Potential participants viewed a description of the survey before electing to participate. Interested participants followed a link from MTurk to an external survey on the Qualtrics platform. Although there has been debate as to the quality of data collected from MTurk participants, past research has documented that it is both a reliable and valid platform for data collection for both the general public population (Buhrmester et al., 2016; Kim & Hodgins, 2017; Cunningham et al., 2017) as well as those with past history of substance use disorders (Strickland & Stoops, 2019). Participants were first screened for eligibility and, if eligible, were provided an information page and asked to confirm or decline participation.

Inclusion criteria for the study included: (a) self-reported age 21+ years (b) self-reported proficiency in reading and comprehending English; (c) current state of residence with

implemented mandatory social distancing procedures, and; (d) self-reported consumption of alcohol on >1 occasions per month, on average, in the past year. Exclusion criteria for the study included a reported history of COVID-19 infection in the 90 days preceding the assessment (to mitigate the effects of COVID-19 infection on alcohol consumption patterns). Additionally, participants residing in states with no mandatory social distancing (e.g., shelter-in-place or equivalent) protocol at the time of data collection were excluded from recruitment; this information was obtained from respective state government websites. The following states were excluded from recruitment: Arkansas, Iowa, Nebraska, North Dakota, Oklahoma, South Dakota, Utah, and Wyoming.

Procedures

Eligible participants were asked to complete a brief survey (duration: approximately 20-30 minutes). The first set of items queried pre-social-distancing demographic characteristics, past-year drinking history, and psychological distress (including emotional and physiological reactions) attributed to COVID-19. To ensure a standardized operational definition of social distancing was used, the Centre for Disease Control definition was provided verbatim to all participants immediately prior to assessment of related outcomes. Participants proceeded to complete two sets of questionnaires assessing drinking motives, alcohol use and related outcomes, depressive symptoms, and environmental reward. Questionnaire sets were identical with the exception of different anchors for timeframes, in order to estimate relative change in these outcomes across two time points (pre-social-distancing and post-social-distancing). Before starting each set of questions participants were provided with the specific instructions for anchoring their replies in a timeframe. For the first battery of questionnaires (i.e., pre-social-distancing timeframe), participants were instructed to anchor their responses to the 30 days

immediately preceding the state-mandated shelter-in-place (or equivalent) protocol (e.g., “In the one-month period prior to the start of the state-mandated shelter-in-place protocol”). For the second battery (i.e., post-social-distancing timeframe), participants were instructed to anchor their responses to the 30 days immediately after the start of state-mandated shelter-in-place (or equivalent) (“In the 30 days immediately after the start of the state-mandated shelter-in-place protocol”). Survey timeframes were individualized based on the individual’s current state of residence; start dates for social distancing orders (obtained from State Government websites) were piped in to the participant’s survey based on their current residence. To standardize instruction sets, the actual start date and timeframe instruction were repeated at the start of each question. Because some states were in the process of ‘re-opening’ at (or soon after) the start of data collection, it was important to anchor responses to the 30-day period after the start of the mandate, rather than the past 30 days.

Five attention-check questions were interspersed throughout the survey as a means of detecting random responding. Additionally, two questions appeared at the end of the survey asking the participant to confirm that they: (1) answered the questions honestly, and (2) paid attention to the questions. These attention checks have been utilized in past research completed via MTurk (Kim & Hodgins, 2017; Cunningham et al., 2017). Participant data were excluded if the participant incorrectly responded to >1 attention checks. Upon completion of the Qualtrics survey, participants were compensated \$2.50 (USD).

Measures

Alcohol Use Disorders Identification Test (AUDIT). The AUDIT is a 10-item scale assessing hazardous alcohol use, symptoms of dependence, and harmful alcohol use in the past year (Saunders et al., 1993). Seven of the ten items are scored on a 4-point Likert scale (response options differ by

question structure). The remaining three items are scored on a 3-point Likert scale. Because total AUDIT score was included as a descriptor for the sample characteristics, AUDIT scores were not anchored to the aforementioned time intervals.

Modified Peritraumatic Distress Inventory (PDI). The PDI is a 13-item scale assessing peritraumatic distress, defined as the emotional and physiological distress experienced by an individual after a traumatic event (Brunet et al., 2001). Items on the scale (e.g., “I felt helpless to do more”) were scored on a 5-point Likert scale from 1 (*not at all true*) to 5 (*extremely true*). The original PDI instructions were altered to specifically capture distress attributed to COVID-19 (e.g., “Please rate the extent to which you have experienced each of the following items during (or immediately after) the COVID-19 pandemic.”). Although exposure to stress surrounding COVID-19 does not constitute experience of a traumatic event per se, the PDI was selected for the purpose of implementing a previously developed measure of emotional distress and physiological arousal secondary to ongoing or recent events (Brunet et al., 2001). As such, this modified measure provided a structured assessment of distress attributable to the ongoing pandemic. Consistent with past research, the overall score on this measure is the mean response across all 13 items.

Alcohol consumption. Indices of recent alcohol use were assessed with the National Institutes on Alcohol Abuse and Alcoholism (NIAAA) Recommended Alcohol Questions¹. The items are as follows: (1) how often did you usually have any kind of drink containing alcohol?”; (2) how many alcoholic drinks did you have on a typical day when you drank alcohol?”; (3) what is the largest number of drinks containing alcohol that you drank within a 24-hour period?”; (4) how often did you drink this largest number of drinks?, and; (5) how often did you have 5 or more (males) or 4 or more (females) drinks containing alcohol within a 2-hour period.” The latter item provides the operational definition of a ‘binge’ drinking episode used in the present study. An additional item was included to query the

amount of time participants typically spend consuming alcohol per day, with options ranging from 1 (0 hours) to 7 (10+ hours).

Solitary Drinking Frequency. Questions on drinking context were adapted from those reported in Keough and colleagues (2018). A single Likert item was used to assess relative frequency of solitary drinking in the specified one month period: “when you drank alcohol, how much of that time was spent drinking while you were by yourself relative to when socializing with other people either in-person or virtually”. Response options ranged from 1 (“100% by yourself”), 2 (90% by yourself, 10% with other people) to 10 (10% by yourself, 90% with other people”), 11 (“100% with other people”). An additional Likert item was used to assess relative frequency of social drinking in in-person relative to virtual contexts: “when you drank alcohol while socializing with other people, how much of that time was spent with other people in-person relative to being virtually”. Response options ranged from 1 (100% in person), 2 (90% in person, 10% virtual) to 10 (10% in person, 90% virtual), 11 (100% virtual).

Alcohol Purchase Task (APT). The APT assesses alcohol demand (Kaplan et al., 2018). Participants were asked to indicate how many drinks they would consume at the following prices: \$0, \$0.50, \$1.00, \$1.50, \$2.00, \$2.50, \$3.00, \$4.00, \$5.00, \$6.00, \$7.00, \$8.00, \$9.00, \$10.00, \$11.00, \$12.00, \$13.00, \$14.00, and \$15.00. Participants were instructed that all drinks were administered as “standard” sizes (equivalent to one standard drink), that they could not stockpile drinks for a later time (i.e., all requested drinks must be consumed), and that they did not drink before and cannot drink after (adapted from MacKillop et al., 2010). Five scores can be generated from the observed APT scores that reflect the latent facets of alcohol demand: intensity (consumption when alcohol is free); breakpoint (the first price that reduces alcohol consumption to 0); Omax (maximum expenditure for alcohol), and; Pmax (the price associated with the maximum expenditure) (Murphy and MacKillop, 2006). Freely available scoring software was used to estimate these observed metrics (Foster et al., 2020).

Drinking Motives Questionnaire – Revised (DMQ-R). The DMQ-R is a 20-item questionnaire that assesses motives to consume alcohol (Cooper, 1994). Items are scored on a 5-point Likert scale from 1 (*almost never*) to 5 (*almost always/always*). The measure has 4 subscales: social (e.g., “Because it helps you enjoy a party”), coping (e.g., “To forget your worries”), conformity (e.g., “Because your friends pressure you to drink”), and enhancement (e.g., “So that others won’t kid you about not drinking”; Cooper 1994). In the present study, responses were anchored to a 30-day timeframe. Of primary interest was the coping subscale score, however, all 4 subscales were scored and included in statistical models (as described in Analytical Plan).

Patient Health Questionnaire (PHQ)-9. The PHQ-9 is a widely used 9-item self-report measure of depression (Kroenke et al., 2001). Participants are asked to rate how often they are bothered by the specific item, ranging from 0 (*not at all*) to 3 (*nearly every day*). To address the aims of this study we adjusted the instructional set to assess a 30-day timeframe, rather than the traditional 14-day timeframe. A single severity score for each timeframe, derived by summing responses to all 9 items, was used as the primary outcome (Kroenke et al., 2001).

Reward Probability Index (RPI). The RPI is a self-report scale designed to measure the availability of response-contingent positive reinforcement (reward probability) as well as the presence of aversive stimuli (environmental suppressors) in an individual’s environment (Carvalho et al., 2011). The RPI accomplishes this with a 20-item scale scored on a 4-point Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*). A single total score was obtained by summing responses across all 20 items. Higher scores on this measure represent both increased access to environmental reward and decreased presence of environmental suppressors.

COVID-19 Impact and Perception. For descriptive purposes, questions were developed to estimate the impact of COVID-19 on individuals’ income and employment; participants were provided

with 8 response options ranging from 1 (*“My income/employment has increased”*) to 8 (*“I have lost 100% of my income/employment”*). Similarly, a non-standardized question assessing worry secondary to COVID-19 was included where participants were asked to indicate how worried they are about COVID-19 ranging from 1 (*“not worried at all”*) to 7 (*“extremely worried”*). These outcomes were included to illustrate the sample characteristics and impact of COVID-19 specifically.

Analysis Plan

To address aim 1, paired samples t-tests were conducted to determine whether observed scores on the specified outcomes of interest were significantly different post-social-distancing compared to pre-social-distancing. Independent samples t-tests were then conducted to determine whether any of the specified outcomes differed as a function of race (as an exploratory analysis). Because our sample was predominantly white (65.5%), we computed a binary variable to compare white participants with non-white participants for the pairwise comparisons.

To address aim 2, an index of alcohol consumption was derived by taking the product of typical alcohol consumption frequency and quantity, NIAAA recommended questions 1 and 2 (Agrawal et al., 2009). This index (*‘alcohol QF’*) was derived for both pre-social-distancing and post-social-distancing timeframes; higher scores on this index are indicative of greater levels of alcohol consumption. The post-social-distancing alcohol QF score served as our primary outcome in our mediation models. However, because we observed significant pre-social-distancing to post-social-distancing differences in frequency of binge drinking and frequency of solitary drinking, we ran additional exploratory models with these specified as the outcome of interest.

Prior to analysis, all variables were assessed for univariate normality and the presence of outliers. All variables were normally distributed. Univariate outliers were defined as data points

that fell outside of ± 3.29 SD of the mean. Outliers were only observed on the RPI scale and APT. These outliers were deemed to be valid points of data but were nonetheless winsorized to ± 3.29 SD to reduce their extreme influence on analyses (Tabachnick et al., 2007). Cases with missing data (assumed randomly missing) were handled on a case-by-case basis for each analysis. The final sample size used in each analysis is included in the results for each model.

To test the mediation hypotheses, mediation effects were examined using Hayes' (2013) PROCESS macro for SPSS. To address the first hypothesis, we modeled the indirect effect of post-social-distancing environmental reward (RPI) on post-social-distancing alcohol QF through post-social-distancing depression severity (PHQ) and post-social-distancing coping motives (DMQ-R coping motive subscale). We included pre-social-distancing alcohol QF, depression, and coping motives as covariates in the mediation model in order to examine associations among post-social-distancing variables *relative to* pre-social-distancing levels. To assess hypothesis 2, we modeled the indirect effect of COVID-19-related distress (PDI) on post-social-distancing alcohol QF through post-social-distancing coping motives. Consistent with hypothesis 1, we included pre-social-distancing alcohol QF and coping motives as covariates. Pre-social-distancing social, enhancement, and conformity motive scores (DMQ-R) were included as covariates in all mediation models. This facilitated the examination of the unique role of coping motives as a mediator. Sex and race were also included as covariates in all mediation models. A mediation effect was deemed to be significant if the indirect effect's 95% bias-corrected bootstrap confidence interval did not contain 0.

Results

Sample and demographics

After screening for eligibility and agreement to participate, 1127 participants proceeded to the survey. Of the 727 participants who were excluded, 5 participants did not agree to participate after reading the information statement and 722 did not meet one or more eligibility criteria. After screening for inattention, 833 cases were retained for analyses. The final sample was mostly male (64.7%) with an average age of 40.76 (SD = 10.65) years. Reported racial backgrounds included White (65.5%); Black or African American (14.9%); Asian or Asian American (6.7%); Hispanic or Latino (6.2%); Alaska Native or American Indian (0.6%); Native Hawaiian or other Pacific Island (0.1%), or more than one identified racial background (1.8%). Most participants were not students (61%) and reported an average household income of \$50,000-\$70,000 per year. On average, participants reported living with 2.37 others (66.1% with family). Table 1 provides a summary of additional sample characteristics.

Self-reported change (pre-social-distancing vs. post-social-distancing) in primary outcomes

Pairwise comparisons of pre-social-distancing and post-social-distancing outcomes are presented in Table 2. Consistent with hypotheses, participants reported greater severity of depressive symptoms post-social-distancing, as well as reported lower reward probability and greater environmental reward suppression post-social-distancing. Overall, participants reported typical quantities and frequency of drinking (NIAAA item 1 and 2) post-social-distancing that were commensurate with pre-social-distancing values. However, participants reported spending more time consuming alcohol and significantly more binge episodes post-social-distancing. As predicted, participants endorsed significantly higher coping motives post-social-distancing compared to pre-social-distancing. Conversely, participants endorsed significantly lower social, conformity, and enhancement motives for drinking post-social-distancing relative to pre-social-distancing. Additionally, participants reported significantly more frequent solitary drinking (but

also more virtual social drinking) post-social-distancing compared to pre-social-distancing.. Results for alcohol demand varied by demand index. Intensity of demand and price associated with maximum expenditure (P_{max}) did not differ from pre- to post-social-distancing. Together, these suggest that both alcohol consumption at no cost and the point at which individual demand transitions from inelastic to elastic, respectively, were consistent across timeframes. Breakpoint in responding was observed to be lower post-social-distancing compared to pre-social distancing whereas maximum expenditure was found to be higher across these timeframes. A lower breakpoint implies participants decreased their consumption of alcohol to zero at a lower cost per unit whereas increased expenditure suggests that participants had a higher maximal response output post-social-distancing compared to pre-social distancing. Together these results might suggest there are subtle changes to some facets of individuals' alcohol demand.

The results of the independent samples t-tests to explore differences in outcome as a function of race are presented in Table 2 (see footnote). Non-white participants reported less frequent alcohol consumption but greater typical quantity of alcohol consumed (both time points). At pre-social-distancing, non-white participants reported higher frequency of binge consumption, greater environmental suppression, and reduced environmental reward probability relative to white participants. Non-white participants reported higher endorsement for all drinking motives subscales at both timepoints. Not reported in the table, non-white participants reported higher levels of COVID-19-related distress and greater severity of depressive symptoms at both timepoints ($p < 0.05$ for both outcomes). Finally, non-white participants scored higher on three indices of alcohol demand (breakpoint, O_{max} , and P_{max}) at pre-social-distancing and post-social-distancing. The remaining measures did not differ by race (all $p > 0.05$).

Indirect association of environmental reward with alcohol use via severity of depressive symptoms and coping motives

A summary of the direct and indirect effects for all mediation models conducted in the study can be found in Table 3. The results of the sequential mediation model examining the indirect effect of environmental reward on alcohol QF through severity of depressive symptoms and coping motives ($n = 644$) are presented in Figure 1. There was a significant indirect effect of environmental reward on alcohol QF via severity of depressive symptoms and coping motives. Specifically, lower levels of reward probability predicted greater severity of depressive symptoms; greater severity of depressive symptoms, in turn, predicted higher levels of coping motives; higher levels of coping motives subsequently predicted increases in alcohol QF. Significant unique indirect effects were also observed through depression and coping motives, in the directions specified above. There was no significant direct effect of environmental reward on alcohol QF. Regarding covariates, race ($b = -1.982$, $SE = 0.770$, $t = -2.574$, $p = 0.010$), pre-social distancing coping motives ($b = -1.556$, $SE = 0.693$, $t = -2.244$, $p = 0.025$), pre-social distancing enhancement motives ($b = 1.516$, $SE = 0.492$, $t = 3.081$, $p = 0.002$), and pre-social distancing alcohol QF ($b = 0.631$, $SE = 0.026$, $t = 24.001$, $p < 0.0001$) all significantly predicted variance in the post-social-distancing alcohol QF outcome. No other covariates were statistically significant predictors of post-social-distancing alcohol QF (all $p > 0.05$).

Results of the exploratory sequential mediation analysis with frequency of binge drinking specified as the outcome ($n = 653$) were consistent with the primary model. There was a significant indirect sequential effect of environmental reward on binge frequency through severity of depression and coping motives ($b = -0.003$, $SE = 0.001$, 95% bootstrap CI [-0.007, -0.001]). There was also a unique indirect effect of environmental reward on binge frequency

through coping motives ($b = -0.006$, $SE = 0.003$, 95% bootstrap CI $[-0.012, -0.003]$) but not through depressive symptoms ($b = -0.008$, $SE = 0.005$, 95% bootstrap CI $[-0.019, 0.000]$). Consistent with the first model, there was no direct effect of environmental reward on binge frequency ($p > 0.05$). Conversely, there were no significant indirect effects in the exploratory model with frequency of solitary drinking specified as the primary outcome ($n = 650$; all bootstrap CIs contained zero). However, there was a significant direct effect of environmental reward on frequency of solitary drinking ($b = 0.087$, $SE = 0.017$, $t = 5.064$, $p < 0.0001$).

Indirect association of COVID-19-related distress with alcohol use via coping motives

The results of the mediation model examining the indirect effect of COVID-19-related distress on typical alcohol consumption quantity and frequency through coping motives ($n = 726$) are presented in Figure 2. There was a significant indirect effect of post-social-distancing COVID-19-related distress on post-social-distancing alcohol QF through coping motives (Table 3). Specifically, higher levels of COVID-19-related distress predicted greater levels of drinking to cope that, in turn, predicted greater alcohol QF. The direct effect of COVID-19-related distress on alcohol QF was not significant, suggesting a full mediation of the effect. Regarding covariates, pre-social-distancing enhancement motives ($b = 1.012$, $SE = 0.479$, $t = 2.114$, $p = 0.035$) and pre-social-distancing alcohol QF ($b = 0.644$, $SE = 0.026$, $t = 25.088$, $p < 0.0001$) significantly predicted post-social-distancing alcohol QF. None of the other covariates reached the threshold of statistical significance (all $p > 0.05$).

For the exploratory analyses examining binge and solitary drinking, we first conducted the mediation analysis with post-social-distancing frequency of binge drinking specified as the outcome ($n = 735$). There was a significant indirect effect of COVID-related distress on binge frequency through coping motives ($b = 0.103$, $SE = 0.031$, 95% bootstrap CI $[0.053, 0.178]$). The

direct effect of COVID-related distress on binge frequency was not significant ($p > 0.05$) suggesting a full mediation of the effect. Finally, we ran the mediation analysis with post-social-distancing with frequency of solitary drinking specified as the outcome ($n = 732$). There were no direct ($b = 0.085$, $SE = 0.160$, $t = 0.0532$, $p = 0.595$) or indirect ($b = -0.070$, $SE = 0.049$, 95% bootstrap CI $[-0.175, 0.022]$) effects observed in this final model, suggesting COVID-related distress was not significantly associated with frequency of solitary drinking.

Discussion

The primary aims of this study were to estimate self-reported changes in alcohol consumption, depression, environmental reward and drinking motives during COVID-19, and to test theoretically based mediation models involving these outcomes. Regarding the first aim, we observed inconsistency in the magnitude and direction of self-reported change across alcohol measures. For example, participants reported a greater frequency of binge drinking, but no change in the quantity and frequency of alcohol use. Self-reported changes in alcohol demand indices were also variable, with some indices suggesting no change (e.g., intensity) and others discordant in the direction of change (e.g., breakpoint, maximum expenditure). Overall, these results suggest variability in the presence and magnitude of alcohol use indices in the context of social distancing related to COVID-19 (e.g., Ahmed et al., 2020).

We also found evidence of greater severity of depressive symptoms and lower levels of environmental reward and higher levels of environmental suppressors post-social-distancing compared to pre-social-distancing. These findings are in keeping with theory and research suggesting that restrictions in access to environmental and social rewards increase risk of depression (e.g., Carvalho and Hopko, 2011), although the current study cannot rule out alternative explanations for this association. Similarly, we also found that positive reinforcement

drinking motives (i.e., enhancement, social) and negative reinforcement motives related to external social contexts (i.e., conformity) decreased post-social-distancing relative to pre-social-distancing. Conversely, self-reported frequency of negative reinforcement drinking motivated by internal contexts (i.e., coping) increased from pre- to post-social-distancing timeframes. Contextual factors surrounding COVID-19 (i.e., social distancing) may contribute to these observed changes in motivations for alcohol consumptions. It is intuitive that externally-motivated reasons for drinking might decrease during periods of social distancing. Similarly, more frequent negative reinforcement motives for drinking are intuitive in the context of observed higher negative affect observed post-social-distancing compared to pre-social-distancing.

Notably, exploratory analyses showed that race was significantly associated with the majority of our predictors (environmental reward, depressive symptoms, motives) and alcohol use outcomes. Generally, non-white participants seemed to be at higher risk for higher drinking levels, riskier drinking patterns, and greater affective distress, when compared to white participants. Because we did not design our study to examine race- and demographic-based differences (e.g., we did not comprehensively assess socioeconomic status), we cannot make meaningful inferences about these differences. Ultimately, the data emphasize the need for additional research to more closely examine how race and other demographic factors have impacted and will continue to impact individuals' response to the COVID-19 pandemic and associated mental health outcomes.

In addition to examining mean-level differences, we also tested theory-based mediation models to examine predictors of alcohol use during the COVID-19 pandemic. The first set of mediation models tested environmental reward as an indirect predictor of alcohol QF post-social-

distancing through severity of depressive symptoms and drinking to cope. Results suggested that: (1) lower levels of environmental reward predicted greater severity of depressive symptoms; (2) greater severity of depressive symptoms predicted higher levels of coping motives, and; (3) higher coping motives, in turn, predicted greater levels of alcohol consumption. In addition to the total sequential mediation effect, both severity of depressive symptoms and drinking to cope also independently mediated the effect between environmental reward and alcohol QF. The second mediation model we tested was also derived from the self-medication model. Here, we tested coping motives as a mediator of the relationship between COVID-19-related distress (secondary to COVID-19) and alcohol use post-social-distancing. The data supported our hypothesis for both typical alcohol QF: (1) higher levels of COVID-19-related distress predicted greater levels of coping motives that, in turn; (2) predicted higher levels of alcohol use post-social-distancing. In exploratory analyses, the results of the two mediation models replicated using post-social-distancing frequency of binge drinking at the primary outcome. Collectively these results are consistent with the self-medication hypothesis, where drinking to cope is hypothesized to mediate the relationship between negative affect (e.g., depression) and alcohol use (Khantzian, 1997; Hawn et al., 2020a).

Because coping motives only partially mediated the hypothesized effects, it remains likely that other factors not assessed here also predict relative change in alcohol use during the COVID-19 pandemic. For example, we found that pre-social-distancing enhancement motives (i.e., drinking to enhance positive states) was significantly related to both alcohol consumption and frequency of binge drinking. While this finding was somewhat unanticipated, enhancement motives are typically strong predictors of alcohol consumption (Kuntsche et al., 2005). Exactly

how changes in motives – and other constructs – predict relative change in alcohol use during the COVID-19 pandemic is an important question for future research.

In our additional exploratory models, we also found that frequency of solitary drinking post-social-distancing was not predicted by COVID-related distress, depressive symptoms, or coping motives. We did, however, observe a significant direct effect of environmental reward on solitary drinking frequency post-social-distancing. Specifically, lower levels of post-social-distancing environmental reward were associated with greater frequency of solitary drinking. This pattern of results suggest that differences in external contextual factors, rather than internal context factors (e.g., mood, COVID-19-related distress, alcohol motives), are more relevant for predicting solitary drinking in the context of COVID-19 emergency measures. This finding is in agreement with other recent research examining alcohol use in the context of COVID-19. Specifically, in a Canadian study of alcohol use during the early stages of the pandemic, living alone (an external context factor) predicted increased solitary drinking, whereas internal context factors did not (Wardell et al., 2020). Because past research has demonstrated that increased frequency of solitary drinking predicts increases in alcohol-related problems (Cresswell et al., 2014; Keough et al., 2018) it is imperative to understand which specific environmental factors during COVID-19 may elevate individuals' risk to develop this pattern of drinking.

Ultimately, the data reported here may help identify different predictors of risky alcohol use during the pandemic. For example, we found that the constraints in environmental reward secondary to COVID-19 were associated with elevated severity of depressive symptoms. These changes, in turn, were associated with relative increases alcohol QF and in the frequency of binge drinking post-social-distancing compared to pre-social-distancing. Binge drinking is considered a high-risk style of drinking, as it is associated with risk for future alcohol-related

problems (Wechsler et al., 1998), significant economic cost (Bouchery et al., 2011) and alcohol attributed-mortality (Stahre et al., 2014). To the extent that interventions oriented towards mitigating the effects of constrained environmental reward secondary to social distancing, this might have beneficial effects on preventing escalations in alcohol consumption and the increased frequency of risky drinking patterns. Similarly, we found that environmental contexts predicted the frequency of alcohol consumption in solitary contexts, which is considered to be a risky pattern of alcohol use due to its relation to future problematic use (e.g., Keough et al., 2018). More generally, both frequency of binge drinking and solitary drinking frequency were greater post-social-distancing compared to pre-social-distancing. Together, the results suggest that individuals may not only consume more alcohol during the pandemic, but may also engage in riskier drinking habits during COVID-19. A critical caveat, however, is that it is currently unknown to what extent the patterns of relative change reported here will remain stable or will continue to change during the COVID-19 pandemic. As such, the long-term impact of these changes is unknown.

There are key limitations of the present research that should be noted. First, our research employed a cross-sectional approach that required participants to selectively report on two distinct timeframes, which may introduce bias. For example, a negative retrieval bias may selectively enhance accessibility of negatively-valenced events for some individuals (e.g., Schraedley et al., 2002). Similarly, simple demand characteristics of the questionnaire due to the timeframe instructional set (i.e., anchor of items batteries to pre-social-distancing and post-social-distancing) might provoke unintentional bias and unduly influence individuals' responses (Orne, 1969). Second, the use of a cross-sectional approach precludes any inference about causality or changes over time. Third, sample representativeness and participant eligibility

criteria restricts generalization of results to the general population. For example, we selected participants based on a minimum frequency of past-year drinking history. As a result, we cannot extend conclusions about findings from this sample to individuals with less frequent patterns of drinking, those abstaining from alcohol, those with remote histories of alcohol use, or alcohol naïve individuals who started drinking during the pandemic or immediately prior. More broadly, our use of a convenience sample from MTurk might limit generalizations to the general population due to sample representativeness. Future research will be essential to address these limitations to confirm the replicability and generalizability of the findings reported here.

Despite these limitations, our results provide initial evidence for factors related to changes in alcohol consumption during COVID-19. Some results are consistent with predictions of increased incidence of alcohol use disorders following the easing of social distancing procedures, at least in certain vulnerable subgroups (e.g., Da et al., 2020). Such knowledge can inform public health initiatives to curb harmful use of alcohol and may provide clinicians with useful knowledge concerning both risk and protective factors for alcohol use during the present, and future, pandemics. Prospective research will be needed replicate the results reported here, and to establish the long-term consequences of these changes observed during the COVID-19 pandemic.

Notes

¹<https://www.niaaa.nih.gov/research/guidelines-and-resources/recommended-alcohol-questions>

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Table 1. Sample characteristics.

	Descriptor
AUDIT Total score - past year (<i>SD</i>)	10.49 (8.13)
Frequency of past-year drinking	
<i>Every day</i>	15.80%
<i>5 to 6 times per week</i>	16.30%
<i>3 to 4 times per week</i>	24.60%
<i>twice a week</i>	22.40%
<i>once a week</i>	13.00%
<i>2 to 3 times per month</i>	7.80%
Living arrangement	
<i>With family</i>	66.1%
<i>Live alone</i>	22.9%
<i>With roommate</i>	8.6%
<i>Other</i>	1.9%
Number of residents in household (<i>SD</i>)	2.37 (1.49)
Income change due to COVID	
<i>Increased</i>	4.3%
<i>No change</i>	41.7%
<i>Reduced up to 10%</i>	12.7%
<i>Reduced by 10-25%</i>	19.1%
<i>Reduced by 25-50%</i>	11.4%
<i>Reduced by 51-75%</i>	4.2%
<i>Reduced by more than 75%</i>	2.0%
<i>100% income loss</i>	4.3%
Change in hours working due to COVID	
<i>Working the same # hours</i>	43.9%
<i>Working more hours</i>	13.2%
<i>Working fewer hours</i>	34.2%
<i>On leave, terminated or quit</i>	8.5%
COVID-related worry (<i>SD</i>)	4.69 (1.67)
PDI Total Score - anchored to COVID (<i>SD</i>)	1.19 (0.93)

Note. AUDIT = Alcohol use disorders identification test. PDI = Peritraumatic Distress Inventory

(anchored to COVID-19).

Table 2. Paired samples t-test statistics.

Outcome	Pre-social-distancing <i>M (SD)</i>	Post-social-distancing <i>M (SD)</i>	<i>t</i>	<i>p</i>
Alcohol QF	17.17 (14.22) ‡	17.33 (13.78)	-0.458	0.647
NIAAA: Frequency	5.18 (1.58)†	5.17 (1.79)†	0.197	0.844
NIAAA: Quantity	3.13 (2.07) ‡	3.14 (1.95) ‡	-0.179	0.858
NIAAA: Time	2.63 (0.93)	2.69 (1.07)	-1.973	0.049
NIAAA: Max drinks	4.01 (1.93)	4.01 (1.93)	1.15	0.25
NIAAA: binge frequency	2.83 (1.97) ‡	3.00 (2.03)	-3.331	0.001
RPI: Reward probability	33.84 (5.69)	30.10 (6.70) ‡	18.759	<0.0001
RPI: Environmental suppressors	26.63 (6.87)†	25.72 (6.56)†	6.502	<0.0001
RPI: Total	60.48 (10.21)†	55.91 (10.09)†	16.087	<0.0001
DMQ: Social motives	2.70 (1.11) ‡	2.05 (1.20) ‡	18.948	<0.0001
DMQ: Coping motives	2.35 (1.09) ‡	2.47 (1.12) ‡	-5.46	<0.0001
DMQ: Enhancement motives	2.79 (1.01) ‡	2.71 (1.03) ‡	3.791	<0.0001
DMQ: Conformity motives	1.89 (1.10) ‡	1.77 (1.14) ‡	6.263	<0.0001
PHQ: Total	6.45 (7.04) ‡	7.40 (7.07) ‡	-7.606	<0.0001
Solitary drinking frequency	6.42 (3.29)	5.14 (3.54)	15.996	<0.0001
Virtual drinking frequency	3.85 (3.43) ‡	5.38 (3.95) ‡	-11.937	<0.0001
APT: Intensity	7.23 (22.24)	6.31 (8.82)	1.511	0.131
APT: Breakpoint	10.72 (4.56) ‡	10.6 (4.68) ‡	1.983	0.048
APT: Omax	32.89 (52.99) ‡	36.62 (73.30) ‡	-2.418	0.016
APT: Pmax	7.60 (4.55) ‡	7.48 (4.56) ‡	1.105	0.269

Notes. NIAAA = National Institute on Alcohol Abuse and Alcoholism (questions from 5-item set). RPI = Reward Probability Index. DMQ = Drinking Motives Questionnaire. APT = Alcohol Purchase Task.

‡Mean score for non-white participants significantly greater than white mean score ($p < 0.05$)

†Mean score for white participants significantly greater than non-white mean score ($p < 0.05$)

Table 3. Indirect and direct effects for hypothesized mediation models.

	Outcome: Post-social-distancing alcohol QF					
	<i>b</i>	<i>SE b</i>	<i>LLCI</i>	<i>ULCI</i>	<i>t</i>	<i>p</i>
Mediation Model 1						
Direct Effect (Reward Probability Index)	0.069	0.056			1.221	0.222
Indirect Effects						
Patient Health Questionnaire	-0.147	0.034	-0.220	-0.084		
Coping motives	-0.051	0.016	-0.088	-0.024		
Sequential effect	-0.028	0.010	-0.054	-0.024		
Mediation Model 2						
Direct Effect (COVID-related distress)	0.988	0.542			1.821	0.069
Indirect Effect (Coping motives)	0.846	0.233	0.465	1.388		

Notes. Mediation model 1: indirect effect of environmental reward on alcohol use sequentially through severity of depressive symptoms and coping motives. Mediation model 2: indirect effect of COVID-related distress on alcohol use through coping motives.

Figure 1. Sequential indirect effect of environmental reward on alcohol QF through severity of depressive symptoms and coping motives. RPI = Reward Probability Index. PHQ = Patient Health Questionnaire. DMQ-R = Drinking Motives Questionnaire – Revised. Alcohol QF = measure of alcohol quantity/frequency (see Analysis Plan). All variables shown in the model correspond to post-social-distancing scores. Environmental reward indirectly significantly predicted alcohol QF through three unique paths: sequentially through depressive symptoms then coping motives; coping motives only, and; depressive symptoms only. Path coefficients are unstandardized b values. Sex and race were included as demographic covariates. Pre-social-distancing covariates included: environmental reward probability, depressive symptoms, motives (coping, enhancement, conformity, social), and alcohol QF. $*p < 0.05$ $**p < 0.01$

Figure 2. Indirect effect of COVID-related distress on alcohol QF through coping motives.

PDI = Peritraumatic Distress Inventory. DMQ-R = Drinking Motives Questionnaire – Revised.

Alcohol QF = measure of alcohol quantity/frequency (see Analysis Plan). Post-social-distancing coping motives and post-social-distancing alcohol QF are shown in the model. COVID-related distress was not anchored to a specific timeframe. The indirect effect of COVID-related distress on alcohol QF through coping motives was significant. Path coefficients are unstandardized b values. Sex and race were included as demographic covariates. Pre-social-distancing covariates included: motives (coping, enhancement, conformity, social), and alcohol QF. $*p<0.05$ $**p<0.01$