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# Getting high to cope with COVID-19: Modelling the associations between cannabis demand, coping motives, and cannabis use and problems

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ABSTRACT

During the COVID-19 pandemic, people may use substances like cannabis for enhancement or coping purposes. Behavioral economic demand for a substance is a key determinant of its use and misuse and can be measured via hypothetical purchase tasks. Previous research suggests that motivations to use a substance play a mediational role between elevated substance demand and problems, but comparable mechanistic research has yet to be done in the COVID-19 context and on the effects of cannabis demand on cannabis use patterns. Participants ($n = 137$) were recruited via the online crowdsourcing platform Prolific. Participants completed measures of cannabis use and problems, motivations for cannabis use, and the Marijuana Purchase Task. Two indices of demand, Persistence (i.e., sensitivity to increasing cost of cannabis) and Amplitude (i.e., consumption of cannabis at unrestricted cost), were related to increased cannabis problems via the use motive of coping during the COVID-19 pandemic. This model did not support the mediational role of enhancement motives. Those with increased cannabis demand who tend to use cannabis to cope are at increased risk of experiencing negative cannabis-related consequences during the COVID-19 pandemic.

## 1. Introduction

Amid the pandemic caused by the novel coronavirus disease (COVID-19), public health measures were enacted in countries around the world to curb the spread of COVID-19. In Canada, wide-scale emergency measures were put in place in March 2020 that severely impacted Canadians' ability to engage in work, educational, recreational, and social activities. During times of high stress and anxiety, social isolation, and limited out-of-home recreational activities such as those seen during the COVID-19 pandemic, people may increase their use of substances like cannabis (Canadian Centre on Substance Use and Addiction, 2020). Cannabis is the most widely used psychoactive substance besides alcohol in Canada, and its use can be accompanied by the risk of developing a cannabis use disorder along with numerous short-term and long-term adverse health consequences (Government of Canada, 2017; Volkow et al., 2014). Alongside the implementation of COVID-19-related emergency measures, a Statistics Canada survey reported a sharp increase in cannabis sales in March and April 2020 compared with previous months (Statistics Canada, 2020). Further, a survey of Canadian adults found that among cannabis users, approximately half increased their use of cannabis relative to their pre-pandemic consumption patterns (Imtiaz et al., 2020). The widespread use of cannabis and an increase in use during the current COVID-19 pandemic underscores the necessity of understanding the etiology of elevated levels of cannabis use.

A key determinant of a substance's use and misuse is its *reinforcing value*, which refers to its behavior-strengthening and behavior-maintaining properties (Bickel et al., 2014). The reinforcing value of a

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substance has been operationalized as behavioral economic demand, or the relationship between the price of a substance and its consumption. Substance-related demand has been measured in the lab through the use of hypothetical purchase tasks (Bickel et al., 2014). Purchase tasks have been employed across a number of substances including alcohol, tobacco, and cocaine (Amlung & MacKillop, 2015; Bruner & Johnson, 2014; MacKillop et al., 2008), and more recently for cannabis (i.e., Marijuana Purchase Task; Aston et al., 2015; Collins et al., 2014). These tasks ask the participant to estimate their consumption of a substance at varying price points (e.g., "How many hits of marijuana would you take if they were $2.00?"). Purchase tasks allow for the characterization of an individual's pattern of demand via the calculation of several demand indices: four observed indices (intensity, $O_{max}$, $P_{max}$, and breakpoint) and one derived index (elasticity). Intensity refers to unconstrained consumption at zero cost. $O_{max}$ refers to the peak expenditure, or the maximum total amount of money spent on the substance across price points. $P_{max}$ is the price at which this peak expenditure occurs. Breakpoint refers to the cost at which consumption is suppressed to zero. Higher values on each of these indices reflect higher demand for the substance. The derived index, elasticity, refers to the rate at which consumption decreases relative to increases in cost. Latent factor analysis of the Marijuana Purchase Task has revealed that these five indices map onto two underlying dimensions of demand. The first factor is "Amplitude," which refers to consumption at unrestricted cost and is comprised of one index, intensity. Higher consumption at zero cost reflects higher demand. The second factor, "Persistence," is comprised of $O_{max}$, $P_{max}$, breakpoint, and elasticity, and reflects the individual's sensitivity to increasing cost (Aston et al., 2017). A low sensitivity to increasing cost indicates higher demand. This factor structure aligns with research demonstrating a similar structure for alcohol and tobacco purchase tasks (Bidwell et al., 2012; MacKillop et al., 2009).

Responses on hypothetical purchase tasks have been shown to be an accurate reflection of demand for the real substance (Amlung et al., 2012), as well as a key determinant of patterns of use and misuse (Aston et al., 2015, 2017; Tucker et al., 2016). For cannabis specifically, higher Amplitude is associated with increased cannabis use quantity and frequency, increased craving, and more symptoms of cannabis dependence (Aston et al., 2015, 2017; Strickland et al., 2017). Higher Persistence is associated with fewer stop attempts or attempts to cut down on cannabis use (Aston et al., 2017). Increased demand for cannabis has also been linked to hazardous behaviors, such as driving after using cannabis (Patel & Amlung, 2019; Teeters et al., 2019). Efforts have been made to identify and better understand the etiological and maintaining factors of substance use disorders (e.g., the Addictions Neuroclinical Assessment) (Kwako et al., 2016). However, currently there is little research on which mechanisms explain the relationship of greater demand for cannabis with its use and associated problems

One potentially relevant factor that may account for the relationship between cannabis demand and outcomes is specific motives for use. Previous research has indicated that for other substances like alcohol, substance demand and specific motives for use are both implicated in consumption and related problems (Dennhardt et al., 2016; Luciano et al., 2020; Yurasek et al., 2011). Those with elevated demand may be more likely to use cannabis for specific reasons or under particular circumstances. Understanding the specific motives for substance use can shed light on when and how much someone is likely to use as well as the potential consequences of their use (Cooper, 1994; Cooper et al., 2016). Motives for cannabis use generally vary along two dimensions: valence (i.e., positive or negative) and source of reinforcement (i.e., internal or external)(Simons et al., 1998). The internal motives of coping and mood enhancement appear to be especially related to negative outcomes, showing associations with worse mental health functioning, greater quantities of cannabis use, and more cannabis-related problems (Bohnert et al., 2018; Bonar et al., 2017; Lee et al., 2007). Research with alcohol demand has indicated that the demand indices of intensity (unconstrained consumption at zero cost) and $O_{max}$ (maximum expenditure on substance) are positively related with alcohol use and problems, and this relationship is mediated by elevated motives of enhancement and coping (Yurasek et al., 2011). Additionally, a study among veterans demonstrated that those with a high valuation of alcohol were more likely to use alcohol for coping and enhancement motives, which in turn predicted more alcohol-related consequences (Dennhardt et al., 2016). Enhancement and coping motives for use are relevant to the COVID-19 pandemic, as individuals with higher levels of demand may be at higher risk of escalating substance use to alleviate the elevated levels of boredom or negative affect. Previous *meta*-analytic research has demonstrated this contextual link, with alcohol demand indices showing significant increases following stress- or negative affect-inducing paradigms (Acuff et al., 2020). The extant literature suggests that motivations to use play a mediational role between elevated substance demand and problems, but comparable mechanistic research has yet to be done on the effects of cannabis demand on cannabis use patterns. This is an especially important area to explore as we see increased levels of cannabis use as the COVID-19 pandemic continues.

The current study is the first to our knowledge to investigate internal cannabis use motives as a potential mediating factor between cannabis demand pre-declaration of COVID-19 emergency measures and cannabis use patterns and problems after the implementation of COVID-19 emergency measures in Canada. To do this, we used a crowdsourcing platform (i.e., Prolific) to examine how pre-existing levels of cannabis demand related to changes in cannabis use and problems during the first 30 days of the COVID-19 state of emergency. Then, we examined the mediating role of internal motives (coping and enhancement). We hypothesized that higher levels of cannabis demand pre-COVID-19 may lead to greater coping or enhancement motives to use cannabis during the COVID-19 pandemic and associated emergency measures. Further, we hypothesized that this mechanism may lead to increased cannabis use and/or problems after the enactment of COVID-19 emergency measures.

## 2. Methods

### 2.1. Participants and procedure

Participants for the study were recruited through Prolific. Prolific is an online recruiting platform where individuals are able to access and complete a host of surveys and studies run by researchers (Palan & Schitter, 2018). Prolific ensures the application of proper recruitment standards and informing participants on their role in research (Palan & Schitter, 2018). Data were drawn from a larger study of alcohol use during the COVID-19 pandemic among Canadian adults (Wardell et al., 2020). Four attention check items, as recommended by Prolific's guidelines, were implemented in this study to ensure data quality (e.g., "Please answer this question by choosing option number two, 'disagree'.") (Marjanovic et al., 2014; Prolific Team, 2018). Participants' data were automatically excluded from the study if they failed 2 or more attention checks and completed all questions in an unrealistically short time (defined as under 20 min in this study; $n = 2$). Of the 400 remaining participants, we selected a subsample that endorsed having used any type of cannabis in the past three months ($n = 159$) for the present analyses. Participants' data were further excluded for missing ($n = 2$) or non-systematic ($n = 20$) data on the Marijuana Purchase Task (see measures). The final sample was comprised of 137 participants.

Data collection was completed from April 30, 2020 to May 4, 2020, approximately 7–8 weeks after the COVID-19 pandemic was declared. A majority of the measures required participants to respond to items by referencing either a month prior to the COVID-19 state of emergency in their area or in reference to the past month (i.e., in the past 30 days, which occurred during COVID-19 states of emergency and restrictions). This study was approved by York University's Office of Research Ethics. All participants were given $13 CAD as compensation.

### 2.2. Measures

#### 2.2.1. Demographics

Participants were asked to report relevant demographic information, including their age, sex, race/ethnicity, level of education, annual household income, and relationship status. Current living situation and employment status prior to the COVID-19 pandemic were also reported.

#### 2.2.2. Cannabis use frequency

A question derived from the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU; Cuttler & Spradlin, 2017) was used to assess the frequency of cannabis use. Two versions of the question were administered; the first required participants to answer in the context of the one-month period prior to the declaration of the COVID-19 emergency in their area, and the second asked participants to refer to their cannabis use in the past month (30 days). Participants responded using a 9-point Likert scale (*0 = I did not use cannabis* to *8 = More than once per day*).

#### 2.2.3. Motives for cannabis use

The Marijuana Motives Measure (MMM; Simons, Correia, Carey, & Borsari, 1998; 25 items) assessed self-reported reasons for which participants use cannabis. Participants responded using a 5-point scale (*1 = Almost Never/Never* to *5 = Almost Always/Always*) based on how frequently in the past month (30 days) their cannabis use was motivated by each of the presented items. The MMM encompasses five domains of motives for cannabis use (i.e., enhancement, conformity, expansion, coping, and social motives), and previous research has provided support for the validity and internal consistency of this measure (Zvolensky et al., 2007). Cronbach's alphas for the scales used for the current sample were 0.91 (coping) and 0.90 (enhancement).

#### 2.2.4. Pre-covid cannabis use problems

The Cannabis Use Disorder Identification Test Revised (CUDIT-R; Adamson et al., 2010, 8 items) screened for symptoms of cannabis use disorder over the past 6 months and was included as a covariate in order to control for pre-existing cannabis problems (before COVID-19). The sum score was calculated from participant responses, reflecting cannabis use and problems. Cronbach's alpha for the current sample was 0.77.

#### 2.2.5. Past 30 days cannabis use problems

The Marijuana Problems Scale (MPS; Stephens, Roffman, & Curtin, 2000, 19 items) was administered to assess for the extent of cannabis-related problems over the past 30 days (e.g., "Has cannabis caused you to have lower productivity", "Has cannabis caused you withdrawal symptoms"). (Items on the MPS are answered via a 3-point scale (*0 = No problem* to *2 = Serious problem*), and the sum score from each participant was used to evaluate this domain. Cronbach's alpha for the current sample was 0.85.

#### 2.2.6. Cannabis demand

Participants completed the Marijuana Purchase Task (MPT) (Aston et al., 2015) to measure individual behavioral economic demand for cannabis, which has been adapted from demand paradigms for other substances (Aston et al., 2015; Jacobs & Bickel, 1999; MacKillop et al., 2008; Murphy & MacKillop, 2006). The MPT asks individuals to think of a typical day when they would use cannabis and was modified for the present study to refer a typical day during the one-month period prior to the COVID-19 state of emergency in their area. Participants are then asked to imagine they only have access to purchase cannabis from the source being presented to them and are given other parameters relevant to the providing source (e.g., 'there are 10 hits of marijuana in a joint'; 'you would consume all of the marijuana you request in a day'; 'the cannabis is of average quality'). Participants are then asked, based on these conditions, to indicate the "number of hits" they would take on an ordinary day at 22 escalating price points (which range from *$0* to *$10*).

### 2.3. Data analysis

All analyses for the study were conducted in SPSS Version 27 and MPlus Version 8.0 (Muthén & Muthén, 2012). The first step in the data analysis was computing the MPT indices. The MPT data were screened for completeness and participants with any missing data were excluded ($n = 2$). MPT data were then evaluated for non-systematic responding according to the criteria proposed by Stein et al. (2015). Four participants' data violated the trend criterion, and one additional participant's data violated both the bounce and reversal criteria and were thus excluded. Because the calculation of elasticity requires variation in consumption across prices, participants whose data did not conform to demand curves (i.e., due to no reported consumption across prices or rectangular demand) were excluded ($n = 15$) (Amlung et al., 2015). The four observed demand indices were then calculated (Murphy & MacKillop, 2006) and outlying values (i.e., $\geq 3.29$ standard deviations above the mean; Tabachnick & Fidell, 2004) were recoded to be one unit higher than the next highest non-outlying value. < 2% of scores were winsorized. Values of 0 were set to an arbitrarily low value of 0.01 to allow for demand curve analyses (Jacobs & Bickel, 1999). Elasticity (denoted as α) was modeled using Hursh and Silberberg's (2008) nonlinear exponential demand curve model in GraphPad Prism 7: $\log_{10}Q = \log_{10} Q_0 + k(e^{-\alpha Q0P} - 1)$. In this model, $Q$ = log units' consumption, $Q0$ = mean consumption at zero cost, $P$ = price, and $k$ = range of log units consumption. Based on mean performance, the overall best-fitting $k$ parameter was determined to be 2.0 and used for all individual demand curves. The inverse value for elasticity (i.e., 1/α) was used to make interpretation more intuitive, aligning with previous work (Aston et al., 2017; Bidwell et al., 2012). Persistence was calculated as the mean of the standardized values of 1/α, $P_{max}$, $O_{max}$, and breakpoint. Amplitude was defined as the participants' intensity value.

Following computation of the MPT Amplitude and persistence scores, bivariate correlations and descriptive statistics were inspected for all substantive path model variables. Next, a path model was conducted, specifying pre-COVID persistence and Amplitude factors as correlated predictors; past 30 days (during COVID) coping and enhancement motives for cannabis use as correlated mediators; and past 30 days cannabis use frequency and related problems as correlated outcomes. Pre-COVID cannabis frequency and pre-COVID level of cannabis use problems (as measured by the CUDIT) were controlled for in the model. Before running the main path model, we examined the normality of all variables. While all variables showed acceptable skew (< 3.0) and kurtosis (< 8.0) values (Kline, 2005), some showed slight positively skew. To correct for this, we used robust maximum likelihood estimation to estimate the model, as well as bias-corrected bootstrapped confidence intervals (CI) to test the presence of indirect effects. Both MLR and boostrapping have been shown to be robust against violations of normality (Muthén & Muthén, 2012). Mediation was considered supported if the indirect effect 95% *CI* did not contain zero (Fritz & MacKinnon, 2007). Model fit of the hypothesized mediation path model was considered good if the CFI was greater than 0.95, the RMSEA was $\leq$ 0.08, SRMR $\leq$ 0.08, and the model $\chi 2$ was non-statistically significant (Hu & Bentler, 1999; Kline, 2005).

## 3. Results

### 3.1. Descriptive statistics and bivariate correlations

The sample was 44.5% female, with a mean age of 30.98 years ($SD$ = 9.47). For further participant demographics see Table 1. Participants generally had not increased their frequency of cannabis use from pre-COVID to past 30 days (during COVID), using cannabis between once and twice a week on average during both periods. With regard to scores on the CUDIT, 35.2% of participants fell above the cut-off for hazardous cannabis use (sum score of $\leq$ 8), and 20.5% fell above the cut-off for possible cannabis use disorder (sum score of $\leq$ 12)(Adamson et al.,

**Table 1**
Descriptive statistics and bivariate correlations.

| | M (SD) | % |
|---|---|---|
| Age | 30.98 (9.47) | |
| Gender | | |
| Man | | 54.7 |
| Woman | | 44.5 |
| Other | | 0.7 |
| Ethnicity | | |
| Caucasian/White | | 73.7 |
| East Asian/South-East Asian/Pacific Islander | | 13.1 |
| South Asian | | 7.3 |
| Hispanic/Latino | | 5.8 |
| Middle Eastern/North African/Central Asian | | 4.4 |
| Black | | 2.2 |
| Aboriginal | | 1.5 |
| Other | | 2.9 |
| Province/Territory | | |
| Ontario | | 54.7 |
| Alberta | | 12.4 |
| British Columbia | | 10.2 |
| Quebec | | 10.2 |
| New Brunswick | | 2.2 |
| Newfoundland and Labrador | | 2.2 |
| Nova Scotia | | 2.2 |
| Saskatchewan | | 2.2 |
| Manitoba | | 1.5 |
| Prince Edward Island | | 1.5 |
| Yukon | | 0.7 |
| Northwest Territories | | 0.0 |
| Nunavut | | 0.0 |
| Annual Household Income | | |
| Less than $20,000 | | 10.9 |
| $20,000 - $39,000 | | 13.9 |
| $40,000 - $59,000 | | 13.9 |
| $60,000 - $79,000 | | 10.2 |
| $80,000 - $99,999 | | 20.4 |
| $100,000 - $149,999 | | 21.2 |
| $150,000 - $199,999 | | 4.4 |
| Over $200,000 | | 4.4 |
| Have children | | 27 |
| Primary form of cannabis used | | |
| Marijuana (i.e., dried bud/leaf of plant) | | 72.5 |
| Concentrates (e.g., oil, wax, shatter) | | 8.5 |
| Edibles | | 16.9 |
| Other | | 2.1 |

*Note.* Ethnicity percentage values sum to greater than 100% as participants were able to endorse more than one option.

2010). 71.5% of the sample used cannabis for solely recreational purposes and 28.5 used either solely for medicinal reasons or for both medicinal and recreational reasons. Both Persistence and Amplitude were significantly correlated with past 30 days cannabis problems, and Amplitude was significantly correlated with past 30 days cannabis use frequency (see Table 2).

### 3.2. Hypothesis testing: Mediation analysis

The initial hypothesized model (Fig. 1) provided a very good to excellent fit to the data ($\chi^2 = 14.30$, $df = 8$, $p = .074$, CFI = 0.983; RMSEA = 0.070 (90% CI [0.000, 0.128]); SRMR = 0.030) and therefore this model was retained and interpreted. Both pre-COVID Persistence and Amplitude facets of cannabis-related demand were positive predictors of both post-COVID coping and enhancement motives. Post-COVID coping motives positively predicted post-COVID cannabis problems (controlling for pre-COVID CUDIT scores), but not post-COVID frequency of cannabis use (controlling for pre-COVID frequency). Post-COVID enhancement motives did not predict frequency of cannabis use or cannabis problems post-pandemic lockdown.[1] In tems of effect size, the two cannabis demand facets explained 49% and 38% in coping and enhancement motives, respectively. The model explained large proportions of variance in both post-COVID cannabis use (75%) and problems (43%).

Regarding mediation effects, two main indirect effects were supported in the model. First, we observed that post-COVID coping motives mediated the effect of pre-COVID cannabis persistence on post-COVID cannabis problems ($\beta = 0.059$, 95%$CI = 0.003, 0.115$). Second and similarly, we also observed that post-COVID coping motives mediated the impact of pre-COVID Amplitude on post-lockdown cannabis problems ($\beta = 0.053$, 95%$CI = 0.002, 0.104$). Overall, our findings suggest that individuals with higher levels of pre-COVID cannabis demand experienced a greater number of cannabis-related problems during the initial stages of the pandemic as a function of their higher coping motives for use.

## 4. Discussion

The present study is among the first to investigate mediational pathways to cannabis use and problems during the COVID-19 pandemic. We aimed to understand the role of indices of cannabis demand on motives for use and patterns of cannabis use and misuse. Previous research has indicated that individual differences in substance demand is a pre-existing factor that may place an individual at vulnerability for increased substance use and problems (e.g., Aston et al., 2017). In line with previous alcohol demand research, we hypothesized that internal motives for cannabis use, specifically coping and enhancement, may mediate this relationship. Our results indicate that two indices of demand, Persistence and Amplitude, were related to increased cannabis problems via the use motive of coping during the COVID-19 pandemic. This model did not support the role of enhancement motives. This finding indicates that those with increased cannabis demand who tend to use cannabis to cope are at increased risk of experiencing negative cannabis-related consequences. This is largely in line with previous research implicating increased cannabis demand in increased cannabis craving, use quantity and frequency, and dependence symptoms (Aston et al., 2015, 2017; Strickland et al., 2017). Of particular note is the finding that the demand facet of Persistence was implicated in this model. Previous research (Aston et al., 2017) has indicated that Amplitude was more associated with increased cannabis use and cannabis-related problems. This difference in finding may be attributable to differences in sample characteristics. The participants in Aston et al. (2017) recruited pre-pandemic from Rhode Island, a U.S. state in which recreational cannabis use is illegal. In contrast, participants in the current study were from across Canada during the COVID-19 pandemic, a country in which recreational cannabis use has been legal for over two years.

Elevated cannabis demand appears to be a vulnerability factor for experiencing cannabis-related problems, and as such early identification and prevention efforts should be targeted at these individuals. This is especially relevant as the COVID-19 pandemic continues, with its associated unprecedented levels of stress and anxiety, both about the virus itself as well as caused by the associated lockdowns and emergency measures, (Horesh & Brown, 2020). Cannabis use has been well-established as a method to cope with stress for some, and this method may be especially salient to those individuals who perceive cannabis to

[1] Given that greater than 50% of our sample reprted having an annual household income of greater than $80,000, we examined the bivariate correlations between income and all cannabis-related variables. We found that income was uncorrelated with all cannabis variables, and thus, we opted not to include it in the main path analysis.

**Table 2**
Descriptive statistics and bivariate correlations.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. Persistence (Pre-COVID) | – | 0.299** | 0.425** | 0.410** | 0.154 | 0.105 | 0.169* | 0.256** |
| 2. Amplitude (Pre-COVID) | | – | 0.572** | 0.425** | 0.521** | 0.489** | 0.379** | 0.203** |
| 3. Coping Motives (Post-COVID) | | | – | 0.620** | 0.444** | 0.494** | 0.572** | 0.478** |
| 4. Enhancement Motives (Post-COVID) | | | | – | 0.390** | 0.375** | 0.493** | 0.318** |
| 5. Cannabis Use (Pre-COVID) | | | | | – | 0.801** | 0.703** | 0.363** |
| 6. Cannabis Use (Post-COVID) | | | | | | – | 0.709** | 0.347** |
| 7. CUDIT (Pre-COVID) | | | | | | | – | 0.631** |
| 8. Cannabis Problems (Post-COVID) | | | | | | | | – |
| *M* | – | 9.723 | 2.171 | 2.847 | 3.088 | 3.214 | 6.197 | 2.553 |
| *SD* | – | 12.449 | 1.157 | 1.236 | 2.477 | 2.774 | 5.313 | 3.878 |
| *Range* | −1.85–2.50 | 0–51 | 1–5 | 1–5 | 0–8 | 0–8 | 0–22 | 0–15.26 |
| *Skew* | 0.90 | 2.23 | 0.71 | −0.07 | 0.72 | 0.57 | 1.06 | 2.14 |
| *Kurtosis* | 0.29 | 4.37 | −0.76 | −1.20 | −0.68 | −1.15 | 0.35 | 5.36 |

*Note*. *M*, mean; *SD*, standard deviation.
* $p < .05$, ** $p < .01$

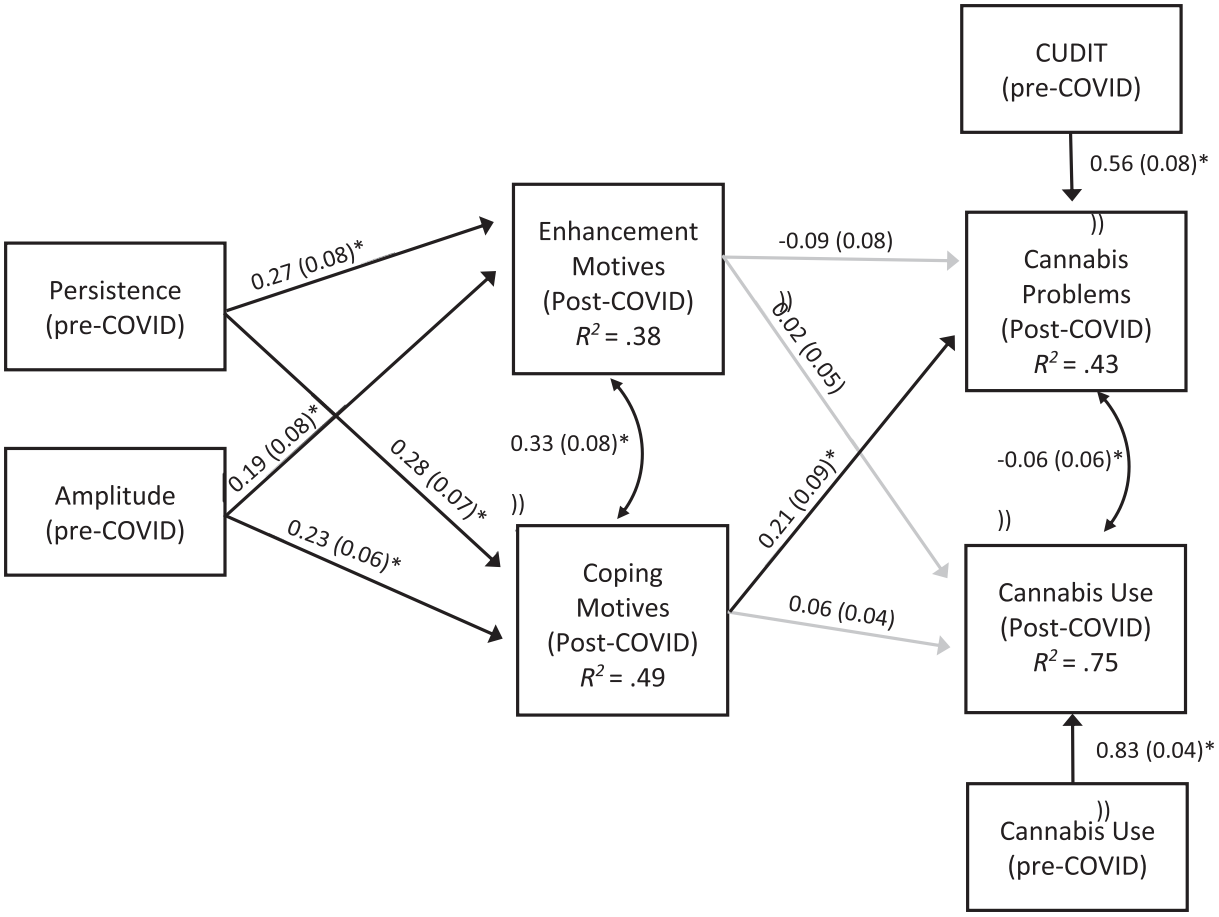


**Fig. 1.** Mediated path model from pre-COVID cannabis demand (Persistence and Amplitude) to post-COVID frequency of cannabis use and problems via post-COVID internal motives for cannabis use (coping and enhancement). Standardized coefficients with standard errors (in brackets) are presented. Solid lines and asterisks denote statistically significant paths ($p < .05$) and gray lines are non-statistically significant paths ($p > .05$).

have a higher reinforcement value (Hyman & Sinha, 2009). Using cannabis to cope is especially relevant in the context of a largescale external stressor like the COVID-19 pandemic. Other research has shown that COVID-19-related worry is associated with using cannabis to cope (Rogers et al., 2020). Those that use cannabis to deal with stressors may be more likely to experience heavier cannabis use and more cannabis-related problems (Hyman & Sinha, 2009). Specifically focusing cannabis interventions on skills for coping with general and traumatic stress might be an important target to improve treatment outcomes (Hyman & Sinha, 2009). In extreme situations like the COVID-19 pandemic and associated lockdowns in which access to formal interventions might be limited, encouraging stress-reducing activities like exercise and yoga may be beneficial (Hyman & Sinha, 2009). Broadly, encouraging the use of more adaptive coping strategies rather than cannabis use is a clear implication of the current research.

The findings of this study must be considered in light of certain limitations. The most significant limitation is the use of cross-sectional data to test a mediational model, and therefore being unable to determine the temporal precedence of variables. Despite this limitation, participants reported their pre-pandemic cannabis use so that we were

able to control for retrospective use. The current research is also limited to the initial period of the pandemic. Since restrictions have been variously lifted and re-implemented in response to COVID-19 case counts, it is important to examine longer term effects of the pandemic on cannabis used and the role of demand using a longitudinal model. Furthermore, the sample size for the current study is modest for testing the hypothesized path model. However, our large $R^2$ effect sizes suggest that we captured strong predictors of cannabis motives and problems during COVID-19 in our study. Next, since the MPT is a measure of hypothetical consumption of cannabis, actual cannabis consumption is not measured by this task. However, previous research has provided evidence for the validity of hypothetical purchase tasks for other substances (i.e., alcohol and tobacco; Amlung & MacKillop, 2015; Amlung et al., 2012; MacKillop et al., 2012). Future research is needed to support the validity of the MPT. Moreover, the MPT instructional set refers to smoking "hits" of cannabis, which may impact its use among those whose primary form of cannabis use is vaping or consuming edibles. Though the majority of the sample in the current study indicated that dried cannabis was their primary form of use, this presents a clear limitation to the ecological validity of the MPT. Recent qualitative research on the MPT has recommended against the use of the term "hits" in favor of "grams" and that the specific mode of cannabis administration be incorporated into future iterations of the MPT (Aston et al., 2021). A further potential limitation is that the study measures were administered online rather than in a laboratory context. This presents several drawbacks when administering the MPT, namely that the research team was not able to emphasize important parts of the instructions or answer questions; it is possible that participants' performance was impacted in a negative way by these factors (Aston & Cassidy, 2019). Also, because our sample was drawn from a larger sample of Canadian drinkers it is possible that cannabis use motives in our sample may have differed systematically from those of cannabis-only users. Co-use of cannabis and alcohol is associated with elevated alcohol demand (Morris et al., 2018), so it is possible that co-use may also systematically impact both cannabis demand and motives for use. Finally, we acknowledge that our sample had a rather high level of income (greater than 50% of participants reported an annual household income > $80,000). While household income was unrelated to cannabis use variables in this study, our findings may not generalize to samples with lower income.

In conclusion, this study replicates a modest body of previous research linking cannabis demand to cannabis-related problems and provides evidence for the role of coping motives in the increased cannabis-related problems experienced by those with elevated cannabis demand. Further research is needed to replicate this research within a sample of cannabis-only users and in a real-world, offline setting. This research will inform best practices for targeted problematic cannabis use interventions.

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### *Contributors*

Matthew Keough and Jeffrey Wardell designed the study and wrote the protocol. Tyler Kempe conducted data collection. Lana Vedelago and Matthew Keough conceptualized the research question and conducted the statistical analysis. Herry Patel, Michael Amlung, and James MacKillop assisted with data analysis. Lana Vedelago wrote the first draft of the manuscript and all authors contributed to the edit and review of the manuscript. All authors have approved of the final manuscript.

### *Conflict of Interest*

James MacKillop is a principal in BEAM Diagnostics Inc., but no BEAM products were used in the data collected. All other authors declare that they have no conflicts of interest.

## CRediT authorship contribution statement

**L. Vedelago:** Conceptualization, Validation, Formal analysis, Visualization, Writing – original draft. **J.D. Wardell:** Methodology, Writing – review & editing. **T. Kempe:** Data curation, Writing – review & editing. **H. Patel:** Methodology, Writing – review & editing. **M. Amlung:** Writing – review & editing. **J. MacKillop:** Writing – review & editing. **M.T. Keough:** Conceptualization, Data curation, Formal analysis, Investigation, Resources, Supervision, Writing – review & editing.

## Declaration of Competing Interest

JM is a principal in BEAM Diagnostics Inc., but no BEAM products were used in the the data collected. No other authors have declarations.

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