Evaluation of the Daily Sessions, Frequency, Age of Onset, and Quantity Questionnaire and its Relations to Cannabis-Related Problems

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Abstract

Cannabis use and the prevalence of cannabis use disorder (CUD) among emerging adults are on the rise. Several indicators of cannabis use (e.g., quantity, frequency) as they relate to negative outcomes have been posited in the extant literature. Despite research examining links between indicators and cannabis outcomes, few assessments of cannabis use indicators exist. The Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU) was developed to assess cannabis use across a range of factors. However, the factor structure of the DFAQ-CU has not been validated. Further, the DFAQ-CU was modeled using reflective strategies despite formative strategies being conceptually appropriate. The present study utilized principal components analyses (PCA), principle axis factoring (PAF), and maximum likelihood factor analysis (MLFA) to evaluate the structure of the DFAQ-CU. PCA yielded a four-component solution; PAF and MLFA resulted in five-factor solutions. Comparison of models suggests that all modeling approaches fail to achieve simple structure and are not appropriate for items of the DFAQ-CU. A series of regression models were conducted using the principle components to examine relations between the DFAQ-CU, cannabis-related problems, and CUD symptoms. Results found medium positive relations between Typicality of Use and Frequency, a small positive relation between Concentrates, and small negative relations between Age of Onset with CUD symptoms and problems. The study informs research and clinical work through the refinement of cannabis use assessment and enhancing our understanding of which aspects of cannabis use (e.g., Frequency) are most indicative of CUD and cannabis-related problems.

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Chapter 1

Introduction

Cannabis Use

Extant literature purports that approximately one-third of adults age 19-28 have used cannabis in the past year (Johnston et al., 2016) and nearly one-fifth of adults have used in the past month (the Substance Abuse and Mental Health Services Administration [SAMHASA] 2012). Further, nearly 7% of adults 19-28 report daily cannabis use (Johnston et al., 2016). Importantly, cannabis use rates continue to rise and are highest among emerging adults (i.e., ages 18-25; Arnett 2000; Degenhardt & Hall, 2012; Bachman et al., 1997).

Previous work has demonstrated a host of deleterious consequences associated with cannabis use. Specifically, cannabis use is linked to verbal learning, memory, and attention deficits (Hanson et al., 2010); school dropout (Lynskey et al., 2003); and decreased academic performance (Phillips et al., 2015). Additionally, cannabis use has been linked to health deficits including respiratory function (Taylor et al., 2000) and the ingestion of cannabis contaminated with mold, fungi, or pesticides, and even ingestion of glass beads which can lead to mouth ulcers, sores, and chest constriction (McLaren et al., 2008).

Perhaps most importantly, prevalence of cannabis use disorder (CUD) is rising. The prevalence of past-12-month CUD rose from 1.5% to 2.9% between 2002-2003 and 2012-2013 and lifetime CUD rose from 8.5% to 11.7% (Hasin et al., 2015a). Emerging and young adults in particular appear to be at risk for developing CUD. In a large nationally representative sample, of those aged 18 to 29 years, 6.9% met criteria for CUD in the past year and 11.0% met criteria for CUD in their lifetime (Hasin et al., 2016). Further, the average age of onset for CUD is 21.7 years and those 18 to 29 have 7.2 times the odds of having a CUD in the past 12 months as compared to those 45 or older (Hasin et al., 2016). Notably, 9.4% of college first years meet criteria for CUD (Caldeira et al., 2008). Among lifetime users, 24.6% of college first years met criteria for CUD (Caldeira, et al., 2008) and 35% of adult users met criteria for cannabis dependence (Bonn-Miller & Zvolensky, 2009). Examination of specific CUD symptoms using ecological momentary assessment found that symptoms of craving and withdrawal peak immediately before use (Buckner et al., 2015). Despite research noting a range of negative outcomes and increased rates of CUD, cannabis use attitudes have become more favorable over time (Gallup, 2016), particularly as cannabis becomes more widely available following shifts in policy over the last decade (Roditis et al., 2016; Carliner et al., 2017; Wall et al., 2016). Given these findings, it is crucial to build an understanding of indicators of cannabis use as they relate to adverse outcomes (e.g., CUD).

Indicators of Cannabis Problems and Cannabis Use Disorder

Frequency

Frequency of cannabis use is perhaps the most commonly examined indicator of cannabis use problems (e.g., Pearson, 2019). Chronic cannabis use (i.e., weekly use) is associated with increased likelihood of cannabis dependence (Hall & Pacula, 2003) and cannabis-related problems (e.g., social, educational, and health consequences; Hall, 2009). Approximately 25% of cannabis users report using cannabis daily (Zeisser et al., 2012). Further, among those meeting criteria for a cannabis use disorder, the mean number of use days in the past year was 225.3 (Hasin et al., 2016), suggesting that those with a CUD use cannabis on more days than not. Two longitudinal studies (Coffey et al., 2003; Swift et al., 2008) found that the odds of having cannabis dependence in emerging adulthood significantly increased as cannabis frequency in adolescence increased (ORs 2.2-23) with approximately one-third of adolescent daily users meeting dependence criteria by age 20 (Coffey et al., 2003). Further, using latent class analysis, Fischer et al. (2010) found that those who initiate early (i.e., before age 15) and use at the highest frequency (i.e., daily or near-daily) are most likely to incur cannabis-related problems.

Cannabis use frequency is significantly related to respiratory problems ($\beta = .06$), social problems ($\beta = .14$), and dependence ($\beta = .18$; Walden & Earlywine, 2008). Additionally, frequency of use relates to health, social, financial, legal, and overall cannabis problems even after controlling for age, sex, and quantity of use (aORs 2.01-11.62; Zeisser et al., 2012). Examination of multiple indicators of cannabis use found that frequency is most strongly related to symptoms of problematic cannabis use across four measures of cannabis use problems (*r*s = .63 - .85) followed by the number of use sessions per day (*r*s= .30 - .47), age of onset (*r*s = -.23- -.28), and quantity of cannabis use (*r*s = .17 - .28; Cuttler & Spradlin, 2017). Related to frequency, as the total number of lifetime uses increases, the likelihood of stopping use decreases, with 23% of those with 100-199 lifetime uses and only 10% of those with 200+ lifetime uses abstaining from continued use (DeWit et al., 2000).

Although there is strong evidence to support the relation between cannabis use frequency and associated problems, there is still a significant portion of the variance in CUDs that is unaccounted for. For example, over 60% of daily cannabis users do not meet criteria for a CUD (Looby & Earlywine, 2007), suggesting that frequency alone is insufficient to explain cannabis problems.

Quantity

Assessment of the quantity of cannabis use poses several challenges. Notably, research has yet to establish a standardized unit of cannabis, making it difficult for individuals to report their consumption (Lopez-Pelayo et al., 2015). Further, individuals are not accurate in reporting their quantity of use, with experienced users significantly over reporting the number of grams in a self-packed joint or bowl (Prince et al., 2018). Additionally, different routes of administration (e.g., inhalation, ingestion) make it difficult to quantify the amount of cannabis consumed, particularly given that the potency of cannabis varies greatly (Gray et al., 2009; McLaren et al., 2008). Another problem that emerges when quantifying cannabis is that cannabis is often consumed in social settings in which cannabis is being shared across multiple individuals (Gray et al., 2009). Existing methods for assessing quantity of use include the number of joints smoked, the number of grams smoked (in ¼, ½, or whole increments or as open response), number of hits taken, or via creation of surrogate joints, blunts, or bowls.

Despite difficulties with assessing quantity, several studies have examined relations between quantity and cannabis-related problems and CUD. Individuals meeting criteria for cannabis dependence reported smoking on average one half ounce of cannabis per week and nearly three joints per day (Stephens et al., 2002). When placed in multivariate models, both direct (i.e., number of quarter ounces consumed per month) and indirect (i.e., average and maximum levels of cannabis intoxication) quantity of use significantly predicted respiratory problems and cannabis dependence symptoms after controlling for frequency of cannabis use (Walden & Earlywine, 2008). Notably, Grant et al. (1998) found that quantity of cannabis use (i.e., number of joints) was more strongly related to both DSM-IV dependence (b = .78) and abuse (b = .62) as compared to frequency of use (b = .27 and b = .22 respectively). Conversely, Zeisser et al. (2012) attempted to create a “standard joint” in which participants were told a joint equals 10 puffs on a joint, 5 hits on a bong or pipe, or 0.5 grams of cannabis. Using this means of assessment, they found that increases in cannabis quantity were significantly related to five cannabis use problems (social/financial/legal; failure to fulfill responsibilities; cannabis urge; concern by friends; and failure to reduce use). However, after controlling for frequency, quantity only remained a significant indicator of failure to fulfill responsibilities.

Although promising evidence exists that quantity of cannabis use predicts cannabis use problems and CUD symptoms, more work is needed to understand the nuances of this relation. For example, quantity as assessed by number of joints/pipes used per day did not account for a significant proportion of the variance in cannabinoid levels in urine samples or number of cannabis problems endorsed after controlling for frequency (Tomko et al., 2018). However, quantity as assessed by average grams per joint (via surrogate joints) did account for a significant proportion of the variance in both outcomes. It may be that single indicators of quantity are insufficient to fully capture the dynamic between quantity of use and associated problems.

Age of Onset

A recent meta-analysis examining the relation between cannabis frequency and quantity as they relate to measures of cannabis consequences found a weighted correlation of .367 across 19 studies (Pearson, 2019), suggesting that a significant proportion of the variance in cannabis-related problems is unaccounted for when using frequency and quantity as the sole indicators. One such factor that may influence the experience of cannabis-related problems and CUD is age of onset (i.e., age of first cannabis use). Age of onset has garnered mixed results as a predictor of cannabis-related problems and CUD. The majority of studies found that earlier age of onset (i.e., adolescence) is associated with development of cannabis dependence (e.g., Hall, 2009; Fischer et al., 2010; Richmond-Rakerd, et al., 2016), particularly when coupled with high frequency of use (DeWit et al., 2000). However, the relation between age of onset and cannabis-related problems may become non-significant when frequency is controlled for (Ellickson et al., 2005). As such, it may be that the relation between age of onset and cannabis-related problems is mediated by frequency of use. Additionally, individuals with a longer history of use (i.e., number of years of use since onset) are at increased risk for continued cannabis use, cannabis-related problems, and cannabis dependence (DeWit et al., 2000). Overall, it appears that earlier age of onset is indicative of increased likelihood of CUD and cannabis-related problems, however, it is unclear if this finding holds when controlling for frequency and quantity of use.

The Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory

The Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU; Cuttler & Spradlin, 2017) was developed to address issues related to assessment of cannabis use. This self-report measure is comprised of 41-items (24 core items and 17 screening items). The 17 screening items are used to establish that participants have used cannabis in their lifetime, to assess for medical reasons of use, to measure estimated THC levels in cannabis, and to determine if participants are currently under the influence of cannabis. Prior to factor analysis, only individuals that endorsed any lifetime cannabis use are retained. During reflective factor analysis, 22 of 24-core items were retained and these items loaded onto six factors of cannabis use: cannabis sessions per day, use frequency, age of cannabis use onset, quantity of loose-leaf cannabis use, quantity of cannabis concentrate use, and quantity of cannabis edible use (Figure 1). These six factors accounted for 77% of the available variance in cannabis use with factor loadings ranging from .45 to .98. Correlations between factors ranged from -.23 to .52. The internal consistency of each factor was assessed using Cronbach's alpha (Kline, 2013). Internal consistency estimates for the factors were as follows: frequency $\alpha = .95$, marijuana quantity $\alpha = .88$, age of onset $\alpha = .81$, cannabis concentrates $\alpha = .76$, and daily sessions $\alpha = .69$. The edible factor only contained one item, as such, internal consistency could not be calculated.

In order to establish validity of the DFAQ-CU, a subset of the original sample (*N* = 645) completed additional measures including the Marijuana Smoking History Questionnaire (MSHQ; Heishman et al., 2001); Timeline Followback (TLFB; Sobell & Sobell, 1992), the Cannabis Abuse Screening Test (CAST; Legleye et al., 2007), the Cannabis Use Disorders Identification Test Revised (CUDIT-R; Adamson et al., 2010), the Marijuana Screening Inventory (MSI-X; Alexander, 2003; Alexander & Leung, 2006), and the Cannabis Use Problems Identification (CUPI; Bashford et al., 2010). The DFAQ-CU demonstrated convergent validity with both the MSHQ and TLFB demonstrating significant correlations across all subscales of the MSHQ and frequency/number of joints of the TLFB. The DFAQ-CU evinced strong predictive validity with high correlations between the frequency factor of the DFAQ-CU and assessments of cannabis problems and use disorder symptoms (i.e., CAST, CUDIT-R, CUPIT, and MSI-X; *r*s .63-.85), moderate correlations between the daily sessions factor and outcome measures (*r*s .30-.47), and small correlations between the age of onset, cannabis quantity, concentrate quantity, and edible quantity factors and outcome measures (*r*s .17-.30). The Alcohol Use Disorder Identification Test (AUDIT; Saunders et al., 1993) was used to test for discriminate validity. The cannabis frequency ($r = .23$), age of onset ($r = -.27$), and edible quantity ($r = .30$) factors were significantly related to the AUDIT. The authors justify these significant correlations with the AUDIT by positing that cannabis users tend to use alcohol at higher levels than non-cannabis users (Cuttler & Spradlin, 2017).

Strengths of the DFAQ-CU include assessment of method of cannabis administration (e.g., loose leaf, edibles, concentrates) and pictures to aid individuals in reporting quantity. Though this is the first psychometrically robust self-report measure of cannabis quantity and frequency, it has yet to be validated outside of the original sample. Further, the current factor structure warrants discussion. Specifically, the quantity of edibles use factor is comprised of a singular item. Creating a latent variable of a singular item is problematic because there is no way to determine the internal consistency of the factor. Additionally, the daily sessions factor is comprised of only two items and the internal consistency of this factor was in the "questionable" range ($\alpha = .69$; Kline, 2013). In fact, only three of the six factors resulted in Cronbach's alpha values in the "good" or "excellent" range (Kline, 2013). As such, it may be that the current factor structure of the DFAQ-CU is not the best-fitting model.

DFAQ-CU: A Formative or Reflective Model?

In addition to the above concerns regarding the DFAQ-CU factor structure, it is also argued that the modeling techniques used to develop this measure were inappropriate. During its formation, the DFAQ-CU was developed applying reflective latent variable modeling (i.e., principal axis factoring and maximum likelihood factor analyses; Cuttler & Spradlin, 2017). However, it is argued that formative modeling is more appropriate. Formative factor analyses are, in their essence, data reduction techniques (Borsboom, 2006) that posit that a collection of items can be reduced to create components. This is opposed to reflective models in which a latent construct exists and items are developed to assess the construct (Borsboom et al., 2003). That is, the primary distinction between formative models and reflective latent variable models is that the former assumes the latent variable is the outcome predicted by manifest indicators whereas the latter assumes the manifest indicators are the outcome predicted by the latent variable. As it relates to the DFAQ-CU, it is theoretically argued that cannabis use frequency, quantity, and age of onset are not preexisting constructs that can be observed by assessing how often or how much an individual engages in cannabis use. Rather, it is conceptually more likely that individual items assessing these cannabis behaviors can be summarized as components in a meaningful way (Borsboom et al., 2003). Put another way, a factor of quantity does not exist prior to items assessing quantity of use. As such, formative analytic strategies are more appropriate for the DFAQ-CU than reflective analytic strategies (Coltman et al., 2007; Borsboom et al., 2004).

Beyond the above theoretical argument that modeling the DFAQ-CU as reflective would result in construct invalidity, work by Rhemtulla et al. (2020) posit myriad conceptual problems that can occur when formative variables are modeled as reflective. Despite the original DFAQ-CU resulting in good model fit, it may still be theoretically and mathematically inappropriate. Of chief importance for the present analyses, these authors note that using latent factors as opposed to composites can result in overestimation of item correlations as well as both the over- and under-estimation of model parameters (Rhemtulla et al., 2020). This occurs because latent modeling assumes that all non-shared variance in the model is unrelated to the construct being measured which ultimately results in misdissattenuation (i.e., overcorrection of “false measurement error,” Rhemtulla, et al., 2020 p. 42) and bias due to overestimation of shared variance and the exclusion of unique variance across factors. Importantly, if items are not modeled correctly, relations among factors and other outcomes (e.g., cannabis-related problems) may not be an accurate depiction of the true relations.

The Proposed Study

The purpose of the current study is two-fold. First, although the DFAQ-CU has been posited as a strong measure of quantity and frequency, its structure has yet to be evaluated in an independent sample. Further, the DFAQ-CU was originally modeled as reflective despite being comprised of items more suited for formative modeling (e.g.,Rhemtulla et al., 2020). This study examined the DFAQ-CU to determine if its structure holds in an independent sample using formative analyses. In addition to suboptimal modeling strategies, the DFAQ-CU was validated in a state that had already passed recreational and medicinal cannabis laws. Evidence on the impacts of medical and recreational legalization has garnered mixed results, with studies of adolescent prevalence rates finding no difference as a result of legality (Carliner et al., 2017; Hunt & Miles, 2015; Imbens & Wooldridge, 2009; Hasin et al., 2015b) but increases in cannabis prevalence in adults as a result of legality (Carliner, et al., 2017; Cerdá et al., 2012; Wen et al., 2015). Further, there is some evidence to suggest that different methods of use (e.g., wax, shatter, oils) may be more common in states in which cannabis is legal (Daniulaityte et al., 2015). As such, the structure of the DFAQ-CU may be different in states without cannabis legality, particularly the quantity of concentrates and quantity of edibles factors of the DFAQ-CU.

Secondly, this study aimed to discern which facets of the DFAQ-CU (i.e., daily sessions, frequency, age of onset, and quantity) most strongly relate to cannabis-related problems and symptoms of cannabis use disorder as specified by the Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition (DSM-5; American Psychiatric Association, 2013). Using different indicators of cannabis use (e.g., quantity and frequency) as they relate to the experience of CUD symptoms enhances our ability to understand who is most at-risk for developing cannabis-related problems (Asbridge et al., 2013). Specifically, as previously noted, emerging adults are at increased risk of developing CUD and cannabis-related problems, making examination of college students especially pertinent.

Research Questions and Hypotheses

Research Question 1. Does the Structure of the DFAQ-CU Replicate in an Independent Sample using Formative Modeling Techniques?

Hypothesis 1. It was hypothesized that the DFAQ-CU structure would not be replicated. Specifically, it was hypothesized that the three quantity factors of the DFAQ-CU would collapse into one component of cannabis quantity, thereby creating a four-component model comprised of age of onset, frequency, daily sessions, and quantity of use (Figure 2). It was hypothesized that the quantity factors would collapse into a single component given that the original DFAQ-CU edibles quantity factor is comprised of a singular item and use of concentrates are not as common in states without legalized cannabis. It was hypothesized that the concentrate and edible quantity items would either drop out of the model due to limited endorsement (Daniulaityte et al., 2015) or would correlate with others items to create a generic quantity of cannabis use component that encompasses all methods of cannabis administration included in the present measure.

Research Question 2. How do the Components of the DFAQ-CU Relate to Cannabis-Related Problems?

Hypothesis 2a. Consistent with the original work (Cuttler & Spradlin, 2017), it was hypothesized that all components of the DFAQ-CU would significantly relate to cannabis-related problems such that greater frequency, greater daily sessions, and greater quantity of use would positively relate to cannabis-related problems. Further, there would be a negative relation between age of onset and cannabis problems such that an earlier age of onset would relate to greater problem endorsement. It was hypothesized that the relation between frequency and daily sessions would exhibit medium to large effect sizes with cannabis related problems (Pearson, 2019; Cuttler & Spradlin, 2017), the quantity component(s) would exhibit a medium effect size (Stephens et al., 2002) and the age of onset component would exhibit a small effect size (Cuttler & Spradlin, 2017; Ellickson et al., 2005).

Hypothesis 2b. It was hypothesized that when placed in a multivariate model, frequency of use, daily sessions, and quantity of use would remain significantly and positively related to cannabis-related problems and that this model would account for a large proportion of the variance in cannabis-related problems (i.e., 70% or greater; Cuttler & Spradlin, 2017). Consistent with previous findings (e.g., Ziesser et al., 2012), it was further hypothesized that the frequency component of the DFAQ-CU would evince the strongest relation with cannabis-related problems.

Research Question 3. How do the Components of the DFAQ-CU Relate to CUD Symptoms?

Hypothesis 3a. Consistent with previous work, it was hypothesized that all components of the DFAQ-CU would significantly relate to CUD such that greater frequency, greater daily sessions, and greater quantity of use would positively relate to CUD symptom endorsement. Further, there would be a negative relation between age of onset and cannabis problems such that an earlier age of onset would relate to greater symptom endorsement. It was hypothesized that the relation between frequency and daily sessions would exhibit medium to large effect sizes with CUD symptoms (Hasin et al., 2016; Cuttler & Spradlin, 2017), the quantity component(s) would exhibit a medium effect size (Walden & Earlywine, 2008) and the age of onset component would exhibit a small effect size (Cuttler & Spradlin, 2017).

Hypothesis 3b. It was hypothesized that when placed in a multivariate model, frequency of use, daily sessions, and quantity of use would remain significantly and positively related to cannabis-related problems and that this model would account for a large proportion of the variance in CUD symptoms (i.e., 70% or greater; Cuttler & Spradlin, 2017). It was further hypothesized that the frequency component of the DFAQ-CU would evince the strongest relation with CUD symptoms (e.g., Walden & Earlywine, 2008).

Research Question 4: Does Modeling the DFAQ-CU as Formative Result in a Different Structure than Modeling the Items as Reflective?

Hypothesis 4a. It was hypothesized that modeling the DFAQ-CU as formative would result in a similar factor structure as modeling the items as reflective. As stated in hypothesis 1a, it was hypothesized that both modeling techniques would result in a four-factor/component solution comprised of age of onset, frequency, daily sessions, and quantity of use. However, the formative model would result in lower item correlations as compared to the reflective model as a result of minimizing misdisattenuation (Rhemtulla et al., 2020).

Chapter 2

Methods

Participants

The target sample size for this study was 400 (see power analysis below). A total of 442 (M_{age} = 19.37, 68.33% female, White, 69.50%, 18.04% Hispanic/Latinx) participants were included in the present analysis. Participants were pulled from an ongoing study of cannabis use behaviors recruited from the Texas Tech University PSY Sona Systems participant pool. Individuals had to be 18 years or older to be eligible to participate. Sona participants received create for their participation to fulfill course requirements. Analyses for the present study utilized a subset of the larger study of individuals that have endorsed lifetime cannabis use.

Study Protocol

Eligible participants were directed to an online survey database, Qualtrics (Qualtrics, 2015, Provo, Utah). Data collection for this study was included as part of a larger study. Participants completed a number of measures regarding demographic and socioeconomic information as well as measures assessing rates of cannabis use and cannabis expectancies. Survey data are anonymous; after completion of the survey, participants were redirected to a separate page to fill in information to receive course credit. There is no way to connect participants' personal information to the survey data. All procedures have been reviewed and approved by the Texas Tech University Institutional Review Board (approval number: IRB2018-29).

Measures

Demographics

Participants completed a baseline demographic measure that includes sex, gender, race, ethnicity, age, socioeconomic status, and other sociodemographic variables.

The Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU; Cuttler & Spradlin, 2017)

The DFAQ-CU was used to assess cannabis use behaviors. As previously discussed, the DFAQ-CU is a self-report scale for assessing frequency, quantity, and age of onset for cannabis use. The original scale, using reflective latent variable analyses, is comprised of 41 Likert-like items (24 core items and 17 screening items) with 22 of the 24 core items loading onto six factors of cannabis use behaviors: daily sessions, frequency, age of onset, marijuana quantity, cannabis concentrate quantity, and edibles quantity (Figure 1).

Prior to factor analysis, the DFAQ-CU items were scored in two ways. First, in accordance with the guidelines proffered by Cuttler and Spradlin (2017), the 22 core items of the DFAQ-CU were transformed into *z*-scores to account for the variability in response options across items. For the second scoring method, the items were scored in an alternative way in which all core items are recoded such that each response range begins with “0” and then proceed numerically in an ordinal fashion. Items were recoded to begin with 0 to account for differences in item responses in the DFAQ-CU survey (i.e., some items begin with 0, some with 1, and some are alphabetical). This second method was used to determine if it is necessary to convert items to *z*-scores or if use of scores using the raw variables perform equally as well or better. Using either scoring method, higher scores on items equated to higher frequency, greater quantity of use, greater number of daily use session, and a later age of onset respectively. Both scoring methods were used to conduct separate PCA analyses to determine the best-fitting model (see Research Question 1). The best-fitting model across the scoring methodologies was used to conduct regression analyses (see Research Questions 2 and 3).

The Brief Marijuana Consequences Questionnaire (B-MACQ; Simons et al., 2012)

The B-MACQ is a self-report measure of cannabis-related problems experienced in the past six months developed from the 50-item Marijuana Consequence Questionnaire. The B-MACQ items are summed to create a total problem score (range: 0 to 21) with higher values representing more cannabis-related problems. The B-MACQ is comprised of 21 dichotomous (yes/no) items. Using Rasch modeling, Simons et al. (2012) found a one-factor solution of cannabis-related problems that evinced good fit ($\chi^2(209) = 321.33$, $p < .01$, RMSEA = .04 (90% CI = .03 – .05), CFI = .96, TLI = .96, WRMR = 1.32). Further, in their sample, the B-MACQ demonstrated good internal consistency ($\alpha = .95$) and accounts for 38.8% in the total variance of cannabis-related problems and the B-MACQ did not demonstrate differential item functioning across genders (Simons et al., 2012). Item severity scores (in logits) range from -3.27 (driving while high) to 2.56 (physical fights due to use; Simons et al., 2012). Overall, the B-MACQ is an appropriate measure for assessing cannabis-related problems.

DSM-5 Cannabis Use Disorder Symptoms

To assess for CUD symptomology, the symptoms of the DSM-5 CUD were presented as 11 dichotomous (yes/no) items with higher scores representing a greater number of CUD symptoms in the past 12 months. A similar approach has been used in the extant literature to assess for CUD symptoms (e.g., Dierker et al., 2018; Compton et al., 2009). Using this approach with DSM-IV criteria, Compton et al. (2009) found good fit for a one-factor dependence/abuse factor (CFI = .98, TLI = .99, RSMSEA = .03) with item discrimination scores ranging from 1.62 to 1.83 and severity estimates ranging from .94 to 3.01. As such, presentation of CUD criterion as dichotomous items appears to be an appropriate method for measuring CUD symptoms.

Analytic Approach

All analyses were conducted using Mplus Version 7.31 (Muthén & Muthén, 1998-2015), SAS 9.4™ software (SAS Institute Inc., Cary, NC, USA), SPSS Version 25.0 (IBM Corp., Armonk, NY, USA), and R version 3.5.1 (R Core Team, 2018). Missing data patterns were analyzed using Mplus software. Prior to analyses, data were screened to assess distribution, skew, kurtosis, outliers, missing data patterns, and assumptions.

Research Question 1: Does the DFAQ-CU Structure Replicate in an Independent Sample using Formative Modeling Techniques?

To assess hypothesis 1a, formative analyses were conducted on the core items of the DFAQ-CU. Prior to analyses, Kaiser-Meyer-Olin (KMO) testing was conducted to ensure that the sample was appropriate for component analyses. The KMO test evaluates the proportion of variance between items that is potentially attributable to common variance. KMO values range from 0 to 1 with greater values indicating higher levels of potential common variance. Consistent with Kaiser's (1974) recommendations, KMO values of .8 or greater are considered good, values between .60 and .79 are considered acceptable, and values below .60 are considered poor fit for sampling adequacy. Additionally, Bartlett's (1950) Test of Sphericity was used to examine redundancy among items to ensure that creation of components/factors is appropriate. A significant p-value (i.e., $p < .05$) indicates that variables are related and suitable for factor/component analysis.

Once items of the DFAQ-CU were determined to be suitable for analysis, principal components analyses (PCA) was used to determine the optimal component structure. PCA is a data-reduction technique in which items are combined linearly to extract factors (or components) in order to account for the maximum possible variance in a set of items. PCA was conducted using a Geomin-rotated oblique solution because it was expected that the components would be correlated. To determine the optimal component solution, the scree plot was examined and Horn's (1965) parallel analysis was conducted. The Horn's parallel analysis method generates random data and performs factor analyses on each random data iteration and then averages the resulting eigenvalues. Components were retained if they outperform the randomly generated eigenvalues within the 95% confidence interval. Horn's parallel analysis is considered the strongest method for determining component and factor retention (e.g., Velicer et al., 2000; Velicer & Jackson, 1990) because it is less susceptible sampling error than Kaiser's rule and less subjective than scree plots. Should the results of the scree plots and parallel analysis have resulted in different solutions, the solution generated by parallel analysis would have been selected given that it is the strongest method of factor/component retention. Horn's parallel analysis for the formative model (i.e., PCA) and reflective models(i.e., principal axis factoring [PAF] and maximum likelihood factor analysis [MLFA]) were conducted using the fa.parallel function under the psych package in R (Revelle, 2020). This function was selected given its ability to handle missing data in its determination of the optimal number of components to retain. Both Horn's parallel analyses were conducted using a 95% confidence interval to avoid overfitting the data.

After determining the number of components and items to retain, Cronbach's alpha (Cronbach, 1951) was calculated to evaluate the internal consistency of each component. Values of .90 and above indicate excellent consistency, values of .80 to .89 are good, .70 to .79 is acceptable, .60 to .69 is questionable, .50 to .59 is poor, and below .50 is unacceptable (Kline, 2013). Should the items of the DFAQ-CU not have been suitable for components analysis, the core items of the DFAQ-CU would have been used as individual indicators for Research Questions 2 and 3.

Research Question 2: How does the DFAQ-CU Relate to Cannabis-Related Problems?

To assess hypothesis 2a, a series of ordinal linear regressions were conducted. The total number of cannabis-related problems as measured by the B-MACQ were independently regressed onto each component of the DFAQ-CU using the best-fitting structure from research question one. To assess hypothesis 2b, a multivariate regression was conducted to assess what proportion of the variance in cannabis-related problems can be captured by the DFAQ-CU. Further, multivariate regression analysis was used to determine which components significantly relate to CUD symptom endorsement above and beyond the other components. Assumptions of ordinal logistic regression (homoscedasticity, proportional odds; Menard, 2002) were tested.

Research Question 3: How Does the DFAQ-CU Relate to Cannabis Use Disorder Symptoms?

To assess hypothesis 3a, a series of ordinal linear regressions were conducted. The total number of DSM-5 CUD symptoms were independently regressed onto each component of the DFAQ-CU using the best-fitting structure from research question one. To assess hypothesis 3b, a multivariate regression was conducted to assess what proportion of the variance in CUD symptom endorsement can be captured by the DFAQ-CU. Further, multivariate regression analysis was used determine which components significantly relate to CUD symptom endorsement above and beyond the other components. Assumptions of ordinal logistic regression (homoscedasticity, proportional odds; Menard, 2002) were tested.

Research Question 4: Does Modeling the DFAQ-CU as Formative Result in a Different Structure than Modeling the Items as Reflective?

To assess hypothesis 4a, the DFAQ-CU was modeled as reflective using PAF and MLFA in order to replicate the analyses of Cuttler and Spradlin (2017). Extant literature has found that PAF outperforms MLFA when there are few indicators per factor; however, MLFA outperforms PAF when there are uneven factor loadings (de Winter & Dodou, 2012). The original factorization of the DFAQ-CU resulted in six factors with one to nine items per factor, making PAF an appropriate method, and factor loadings ranging from .46 to .94, making MLFA an appropriate method. PAF and MLFA were conducted using a Geomin-rotated oblique solution because it was expected that the factors would be correlated.

As with research question one, scree plots and Horn's parallel analysis were used to determine the optimal number of factors to retain. Following identification of the optimal number of factors, specific item factor loadings were examined. Individual items with factor loadings greater than .45 were retained (Kite & Whitely, 2018). Items were allowed to cross load if an item has a loading of .45 or greater on multiple factors. It should be noted that allowing items to cross load can impact measurement interpretation as it reduces model parsimony and can lead to factors or components that are less clear as compared to models in which items are only considered to be an indicator of a singular factor or component. Next, Cronbach's alpha and Omega were calculated for to assess the reliability of each factor (McDonald, 1999). Additionally, in order to test the replicability of the factors, H was calculated with values of .80 or greater indicating that the latent variable is well-defined (Hancock & Mueller, 2001; Rodriguez et al., 2016). The best-fitting model using these reflective approaches was then compared to the formative component solution obtained in research question one. The models were compared to determine if these modeling techniques result in different structures and if so, which structure makes the greatest conceptual sense. Additionally, models were compared to assess which method results in higher internal consistency estimates, correlations, and parameter estimates.

Power Analysis

Research Question 1

Several guidelines for minimum sample sizes in formative component analyses have been proffered including recommendations based on the proportion of indicators to components, the number of hypothesized components, and the ratio of participants to indicators with an overall "rule" that larger sample sizes are better for analysis (Osborne & Costello, 2004). A simulation study by Saccenti et al. (2016) found that to achieve high congruence with the population (i.e., congruence of 0.9 or greater) in a sample with few variables (i.e., less than 50), a sample size of approximately 300 is needed. Given that this is first reevaluation of the DFAQ-CU and the original factor structure resulted in wide variability in communalities (i.e., the proportion of the variance in a manifest variable that is explained by the factor), a conservative sample size of 400 was proposed to account for potential differences in structures and variability in factor loadings/eigenvectors in this sample as compared to the original DFAQ-CU solution.

Research Question 2

The G*Power program (Faul et al., 2007) was used to determine the necessary sample size needed to conduct univariate and multivariate linear regression analyses. To conduct the power analysis for hypothesis 2a, linear regression modeling was used. To achieve power of 0.8 for a medium effect size (i.e., standardized beta = .30) with an alpha of .05, and six indicators, 98 participants were needed. To conduct the power analysis for hypothesis 2b, multiple linear regression was used. To achieve power of 0.8 for a medium effect size (i.e., standardized beta = .30) with an alpha of .05, and six variables (i.e., the six factors of the DFAQ-CU), 146 participants were needed.

Research Question 3

The G*Power program (Faul et al., 2007) was used to determine the necessary sample size needed to conduct multiple linear regression analyses. To conduct the power analysis for hypothesis 3a, linear regression modeling was used. To achieve power of 0.8 for a medium effect size (i.e., standardized beta = .30) with an alpha of .05, and six indicators, 98 participants were needed. To conduct the power analysis for hypothesis 3b, multiple linear regression was used. To achieve power of 0.8 for a medium effect size (i.e., standardized beta = .30) with an alpha of .05, and six variables (i.e., the six factors of the DFAQ-CU), 146 participants were needed.

Research Question 4

Several guidelines for minimum sample sizes in formative factor analyses (i.e., MLFA and PAF) have been proffered including recommendations based on the proportion of indicators to factors, the number of hypothesized factors, and the ratio of participants to indicators. A simulation study by Mundfrom et al. (2005) found that to achieve good fit or better (i.e., $K \geq .92$), assuming six factors with an indicator to factor ratio of approximately 4:1 and wide variability in communalities (i.e., the proportion of the variance in a manifest variable that is explained by the factor), a sample size of 300 was needed.

Chapter 3

Results

Frequencies for multiple choice item responses and means and ranges for free response items of the core items of the DFAQ-CU prior to data transformations are presented in Table 1. KMO and Bartlett's tests were conducted on both the *z*-scored and recoded variables to determine which scoring method should be use. The *z*-scored and recoded variables resulted in KMO values of .68 and .65 respectively. Further, both scoring methods resulted in significant Bartlett's tests ($p < .001$), suggesting items were acceptable for components and factor analyses. Given the higher KMO for the *z*-scored variables, the *z*-scored items were used for subsequent analyses. Prior to factor analyses, items were winsorized such that values exceeding 3.29 standard deviations were replaced to correspond to 3.29 standard deviations from the mean in order to minimize the influence of extreme values (e.g., consuming one ounce of cannabis per smoking session; Tabachnick et al., 2007).

Research Question 1. Does the DFAQ-CU Structure Replicate in an Independent Sample using Formative Modeling Techniques?

Prior to principle components analysis, Horn's parallel analysis for principal components was conducted using a 95% confidence interval on 10,000 iterations with the fa.parallel and paran functions in R (R Core Team, 2018). Additionally, the scree plot was examined. Horn's parallel analysis and the scree plot indicated a four-component solution (see Figure 3 for solution and eigenvectors). Items were included in any component in which the item exhibited an eigenvector of .45 or greater. As such, items

10, 11, 12, 19, and 20 were included on both the Frequency and Typicality of Use components.

Of the four components, the Frequency component (e.g., “How many days of the past week did you use cannabis?”) is comprised of 10 items with eigenvectors ranging from .45 to .96 (see Table 2). The Typicality of Use component (e.g., “How many times a day, on a typical weekend, do you use cannabis?”) is comprised of nine items with eigenvectors ranging from .45 to .93. The Concentrates component (e.g., “How many hits of cannabis concentrates did you personally take yesterday?”) is comprised of four items with eigenvectors ranging from .72 to .93. Lastly, the Age of Onset component (e.g., “How old were you when you FIRST STARTED using cannabis regularly [2 or more times/month]?”) is comprised of four items with eigenvectors ranging from .76 to .89. Of note, all cross-loading items had eigenvectors of .45 or greater for the Frequency and Typicality of Use components, suggesting overlap in these constructs. Overall, the PCA model with four components accounted for 73.13% of the total available variance. Correlations between components ranged from -.25 (Frequency and Age of Onset) to .90 (Frequency and Typicality of Use; see Table 3). Cronbach’s alphas (Cronbach, 1951) were then calculated to determine the internal consistency of each component (see Table 4). The Frequency ($\alpha = .94$) and Typicality of Use ($\alpha = .91$) components evinced excellent internal consistency. The Age of Onset component ($\alpha = .87$) was good, and the Concentrates component ($\alpha = .76$) was acceptable.

Research Question 2. How does the DFAQ-CU Relate to Cannabis-Related Problems?

Ordinal linear regressions were conducted to determine relations between the four PCA components and cannabis-related consequences (see Table 5). The Frequency (β = .38, $p < .001$, $r^2 = .14$) and the Typicality of Use (β = .42, $p < .001$, $r^2 = .17$) components evinced medium, positive relations with cannabis consequences such that as frequency and typical levels of use (e.g., quantity and frequency in a typical day) increase, the number of consequences incurred increases. Similarly, the Concentrates (β = .18, $p = .001$, $r^2 = .03$) component evinced a small, positive relation with cannabis consequences such that as quantity/frequency of concentrate use increases, the number of consequences incurred increases. The Age of Onset component (β = -.26, $p < .001$, $r^2 = .07$) evinced a small, negative relation with use such that as age of first/regular use decreases (i.e., as individuals report earlier onsets of cannabis use), the number of problems increases. When placed into a multivariate model, the Typicality of Use (β = .31, $p = .006$) and Age of Onset (β = -.17, $p = .001$) components maintained their significance (see Table 6). However, the Frequency (β = .11, $p = .34$) and Concentrates (β = .02, $p = .76$) components were no longer significant. The overall model evinced a large effect size with cannabis use problems ($r^2 = .24$, $p < .001$; see Table 6). These findings were generally consistent with hypotheses *2a* and *2b*. The Frequency component may not have maintained significance due to overlap with the Typicality of Use component (i.e., multicollinearity due to five shared items on these components). To test this hypothesis, a second multivariate model was conducted in which the Typicality of Use component was removed to determine if the Frequency component maintained significance in the absence of this component. When Typicality of Use is removed, the Frequency component maintained significance (β = .37, $p < .001$).

Research Question 3. How does the DFAQ-CU Relate to Cannabis Use Disorder Symptoms?

Ordinal linear regressions were conducted to determine relations between the PCA components and DSM-5 cannabis use disorder (CUD) symptoms (see Table 7). The Frequency (β = .39, $p < .001$, $r^2 = .15$) and Typicality of Use (β = .43, $p < .001$, $r^2 = .18$) components evinced medium, positive relations with CUD symptoms such that as the frequency and typical use patterns increase, the number of symptoms incurred increases. The Concentrates component (β = .16, $p = .003$, $r^2 = .03$) evinced a small, positive relation with CUD symptoms such that as quantity and frequency of concentrate use increases, the number of symptoms incurred increases. The Age of Onset component (β = -.16, $p < .001$, $r^2 = .03$) evinced a small, negative relation with CUD such that as age of first and regular use decreases, the number of CUD symptoms increases. When placed into a multivariate model, only the Typicality of Use (β = .25, $p = .004$) component maintained its significance (see Table 8). The Frequency (β = .10, $p = .35$), Concentrates (β = -.01, $p = .87$) and Age of Onset (β = -.09, $p = .09$) components were no longer significant. The overall model evinced a medium-to-large effect size with CUD symptoms ($r^2 = .24$, $p < .001$; see Table 8). These findings were generally consistent with hypotheses *2a* and *2b*. Again, due to the high correlation and five shared items between the Frequency component and the Typicality of Use component, a second multivariate model was conducted in which the Typicality of Use component was removed to determine if the Frequency component maintained significance in the absence of this component. When Typicality of Use was removed, the Frequency component maintained significance ($\beta = .41$, $p < .001$), evidencing multicollinearity between the Typicality of Use and Frequency components.

Research Question 4. Does Modeling the DFAQ-CU as Formative Result in a Different Structure than Modeling the Items as Reflective?

Parallel analysis for factor analysis was conducted in R using the fa.parallel and paran functions using the 95% confidence interval with 10,000 iterations. Parallel analysis and scree plots both indicated a five-factor solution. To assess hypothesis 4a, the DFAQ-CU was modeled as reflective using principal axis factoring (PAF) and maximum likelihood factor analysis (MLFA) in order to replicate the analyses of Cuttler and Spradlin (2017). Both PAF and MLFA were conducted using a Geomin-rotated oblique solution to better account for correlations between factors.

Principal Axis Factoring

The PAF model resulted in a five-factor solution accounting for 75.60% of the total variance (see Table 9 and Figure 4). As previously noted, items were considered to load onto any factor in which the item exhibited a factor loading of .45 or greater. As such, eight total items cross-loaded (i.e., had factor loadings of at least .45 on more than one factor) using PAF. Items 3, 6, 7, 10, 11, and 12 cross-loaded onto the Frequency and Typicality of Use factors and items 18 and 19 cross-loaded onto the Typicality of Use and Quantity factors. The Frequency factor (e.g., “How many days of the past week did you use cannabis?") is comprised of eight items with loadings ranging from .51 to .97. The Typicality of Use factor (e.g., "On a typical day you use marijuana, how many sessions do you have?") is comprised of 10 items with factor loadings ranging from .47 to .92. The Concentrates factor (e.g., "How many hits of cannabis concentrates did you personally take yesterday?") is comprised of four items with loadings ranging from .65 to .92. The Age of Onset factor (e.g., "How old were you when you FIRST STARTED using cannabis regularly [2 or more times/month]?") is comprised of four items with loadings ranging from .72 to .88. Finally, the Quantity factor (e.g., "In a typical session, how much marijuana do you personally use?") is comprised of four items with loadings of .58 and .85. Correlations between factors ranged from -.22 to .97 (see Table 10).

The PAF model resulted in a high degree of cross-loading with 8 of the 22 items loading onto two factors (i.e., factor loadings ≥ .45 on more than one factor), highlighting an absence of simple structure when modeling the items as reflective. Notably, all items that cross-loaded loaded onto the Typicality of Use factor and one other factor suggesting that this factor may not be distinct when modeling the DFAQ-CU as reflective. This is further demonstrated by a correlation of .97 between the Frequency and Typicality of Use factors. Specifically, of the eight items meeting the threshold (i.e., factor loadings ≥ .45) to load onto the Frequency factor, six items cross-loaded onto the Typicality of Use factor. Additionally, two of the four items loading onto the Quantity also loaded onto Typicality of Use/Frequency. The Concentrates and the Age of Onset factors did not demonstrate any cross-loading, suggesting that these factors are distinct from the other factors of the DFAQ-CU. Cronbach's alphas (Cronbach, 1951) and Omega (McDonald,

1999) were calculated to determine the internal consistency of each factor (see Table 3). The Frequency, (α = .94, ω = .95) and Typicality of Use (α = .94, ω = .93) evinced excellent internal consistency. The Age of Onset factor (α = .86, ω = .88), and Quantity factor (α = .86) demonstrated good consistency and the Concentrates factor (α = .75, ω = .84) was acceptable-to-good. H values for the factors ranged from .86 (Concentrates) to .98 (Quantity), suggesting that all PAF factors demonstrate replicability and are considered well-defined latent variables (see Table 4).

A supplemental confirmatory factor analysis (CFA) was conducted using the PAF factor structure to determine model fit with items able to cross load onto multiple factors in line with the PAF model extracted. The CFA model resulted in an RMSEA of .09 and a CFI of .86, suggesting that this structure is suboptimal (Hu & Bentler, 1999). When simple structure was assumed, the CFA model resulted in a an RMSEA of .10 and a CFI of .80. Further, a CFA was conducted using simple structure in which the Frequency and Typicality of Use factors were combined. This model resulted in an RMSEA of .12 and a CFI of .75, suggesting poor fit.

Maximum Likelihood Factor Analysis

MLFA also resulted in a five-factor solution accounting for 73.01% of the total variance (see Table 11 and Figure 5). Again, items were considered to load onto a factor if they exhibited a factor loading of .45 or higher. As with the PAF model, the MLFA model resulted in a high degree of cross-loading (i.e., factor loadings ≥ .45 on more than one factor). Specifically, 12 of 22 items loaded onto more than one factor using MFLA, again suggesting a lack of simple structure. Specifically, items 2, 3, 6, 7, 9, 11, and 12 loaded onto the Frequency and Typicality of Use factors; items 8, 18, 19, and 20 loaded onto the Quantity and Typicality of Use factors; and item 10 cross-loaded onto the Frequency, Quantity, and Typicality of Use factors. The Frequency factor (e.g., "How many days of the past week did you use cannabis?") is comprised of eight items with loadings ranging from .51 to .97. The Typicality of Use factor (e.g., "On a typical day you use marijuana, how many sessions do you have?") is comprised of 12 items with factor loadings ranging from .45 to .90. The Concentrates factor (e.g., "How many hits of cannabis concentrates did you personally take yesterday?") is comprised of four items with loadings ranging from .60 to .99. The Age of Onset factor (e.g., "How old were you when you FIRST STARTED using cannabis regularly [2 or more times/month]?") is comprised of four items with loadings ranging from .57 to .97. Finally, the Quantity/Sessions factor (e.g., "In a typical session, how much marijuana do you personally use?") is comprised of seven items with loadings of .52 and 1.00. Correlations between factors ranged from -.29 to .98 (see Table 12).

As noted, the MFLA solution yielded a solution with 12 of the 22 items loading onto two or more factors, demonstrating a lack of simple structure. Notably, all items that cross-loaded loaded onto the Typicality of Use factor and one or two additional factors, again suggesting that this factor may not be distinct when modeling the DFAQ-CU as reflective. As with the PAF model, an extremely high correlation of .98 between the Frequency and Typicality of Use factors corroborates the lack of distinction amongst these reflective factors. Specifically, of the eight items loading onto the Frequency factor, all eight items cross-loaded onto the Typicality of Use factor. Additionally, five of the seven items loading onto the Quantity factor also loaded onto Typicality of Use. Items of the Concentrates and Age of Onset factors did not demonstrate any cross-loading, suggesting that concentrate use and age of use are distinct from the other factors of the DFAQ-CU. Again, Cronbach's alphas (Cronbach, 1951) and Omega (McDonald, 1999) were calculated to determine the internal consistency of each factor (see Table 3). The Frequency ($\alpha = .94$, , $\omega = .95$) and Typicality of Use ($\alpha = .94$, $\omega = .95$) factors evinced excellent internal consistency. The Age of Onset factor ($\alpha = .86$, $\omega = .88$), and Quantity/Sessions factor ($\alpha = .87$, $\omega = .86$) demonstrated good consistency and the Concentrates factor ($\alpha = .75$, $\omega = .84$) was acceptable-to-good. H values for the factors ranged from .86 (Concentrates) to .96 (Frequency and Typicality of Use), suggesting that all MLFA factors demonstrate replicability and are well-defined latent variables (see Table 4).

A supplemental CFA of the MLFA structure in which items were able to cross-load yielded an acceptable RMSEA (.08) but a suboptimal CFI (.86) suggesting poor model fit (Hu & Bentler, 1999). Additionally exploratory CFAs were conducted following the MFLA. First, when simple structure was assumed, the CFA model resulted in a an RMSEA of .10 and a CFI of 81. Second, a CFA using simple structure in which the Frequency and Typicality of Use factors were combined resulted in an RMSEA of .11 and a CFI of .78. Both models suggest poor fit to the data.

Model Comparisons

Due to missing data as a result of skip logic in the DFAQ-CU on items related to concentrates and age of onset, mean scores for each participant on each component were used in the correlation analysis. Examination of the relations among the PCA components, PAF factors, and MLFA factors found correlations ranging from -.29 to 1.00 (see Table 13). Correlations of 1.00 are the results of identical items on age of onset and concentrates components and/or factors across modeling techniques. Notably, regardless of method used (i.e., PCA, PAF, MLFA), components and factors comprised of identical items (i.e., Age of Onset, Concentrates) were highly correlated. The primary question for these set of analyses was to determine if formative and reflective models yielded similar structures. These results found that, though the PAF and MLFA models had similar factors as compared to the PCA component solution, the amount of cross-loading in the PAF and MLFA models suggests differing outcomes as a result of modeling techniques with regard to simple structure. The PCA model resulted in less cross-loading than the PAF and MLFA models. Further, the CFI values obtained from CFAs for the PAF and MLFA models (.86 and .89 respectively) demonstrate that the structures of these models are suboptimal.

As noted above, the mean of items within a component were used as the component score for the PCA. However, in PCA modeling, components scores are derived by multiplying an individual's score on each item by the corresponding eigenvector and summing these values to create a singular score for each component. Due to skip logic questions, many participants were missing data related to concentrates and age of onset. As such, a value of "0" was used as the participant score in order to calculate participant component scores. The correlations between PCA components and the PAF and MLFA factor scores using this methodology are presented in Table 14.

Using this method resulted in much higher correlations between the concentrates and age of onset components/factors and the other variables of interest, likely due to the need to replace missing data with zeros. Globally, this points to a larger flaw in the DFAQ-CU as a whole. Namely, true component scores cannot be calculated without bias, necessitating that “components” be calculated as the means of the individual items within a component.

Exploratory Analyses

To determine if use of reflective modeling techniques on formative variables results in overestimation of effects with cannabis-related outcomes, univariate analyses were conducted to examine relations between PAF and MLFA factors as they relate to cannabis consequences and CUD symptoms. Results indicated that both PAF and MLFA generally resulted in slightly larger effect sizes for both consequences and CUD symptoms (see Tables 5 and 7). In particular, the Age of Onset component resulted in the largest differences in effect size. The PCA Age of Onset component resulted in an r^2 of .07 with consequences as compared to r^2s of .14 for both PAF and MLFA. Similarly examination of CUD symptoms yielded an r^2 of .03 using the PCA Age of Onset component whereas PAF and MLFA results in r^2s of .07. For comparable components/factors (e.g., PCA Concentrates and PAF Concentrates) and subsequent outcomes, r^2s differed by up to .07.

Chapter 3 Corresponding Figures and Tables

Figure 1

Factor Structure of the Original Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Inventory Modeled as Reflective.

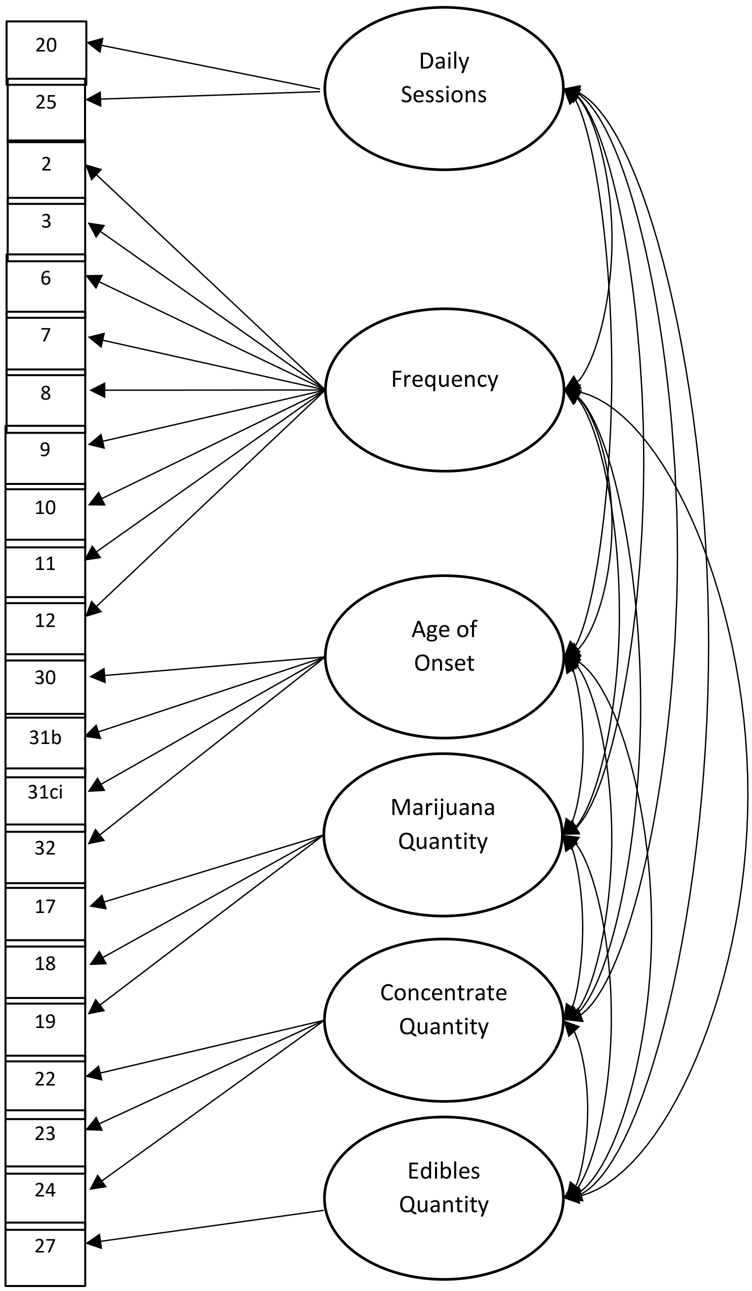
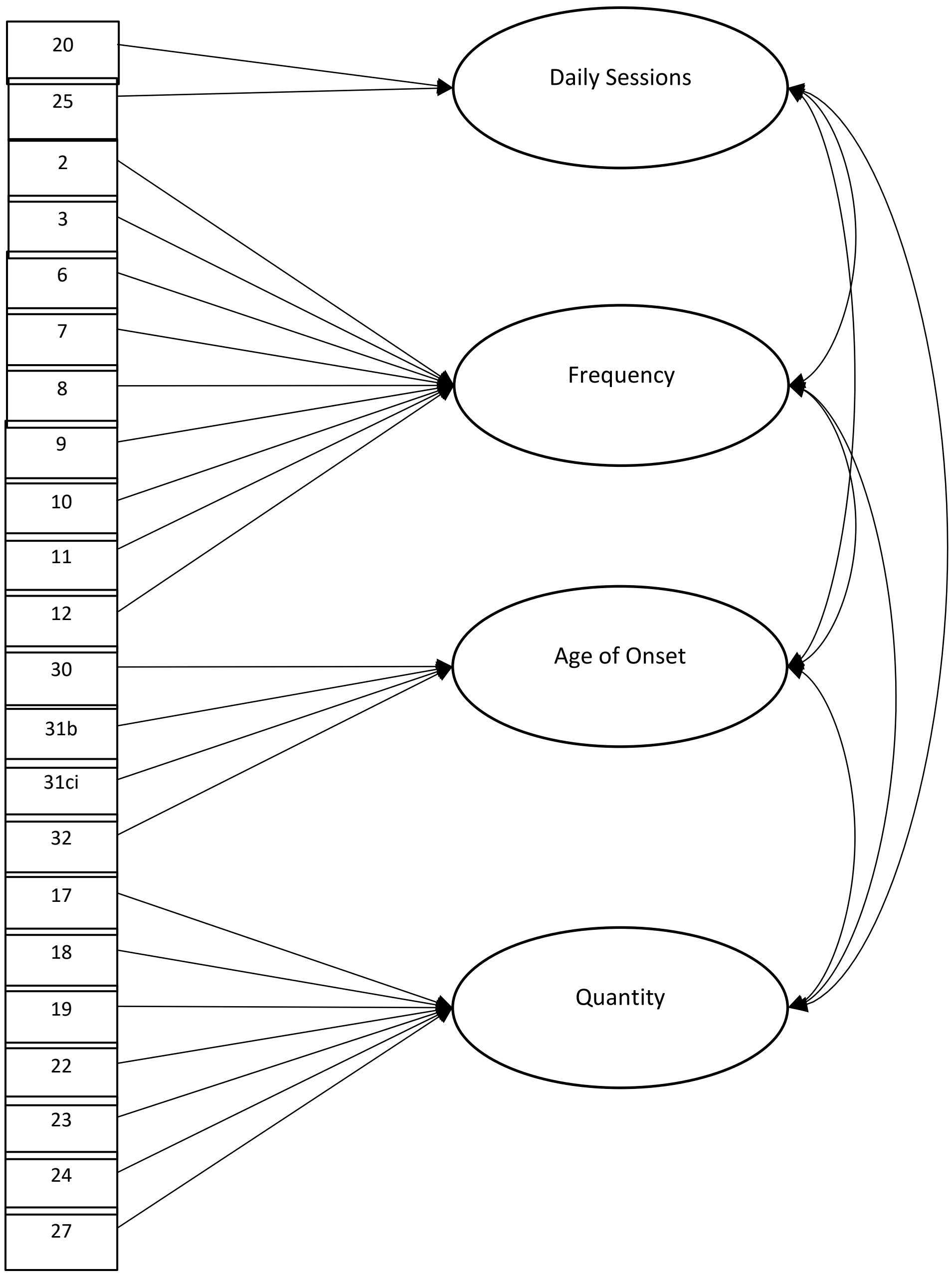


Figure 2

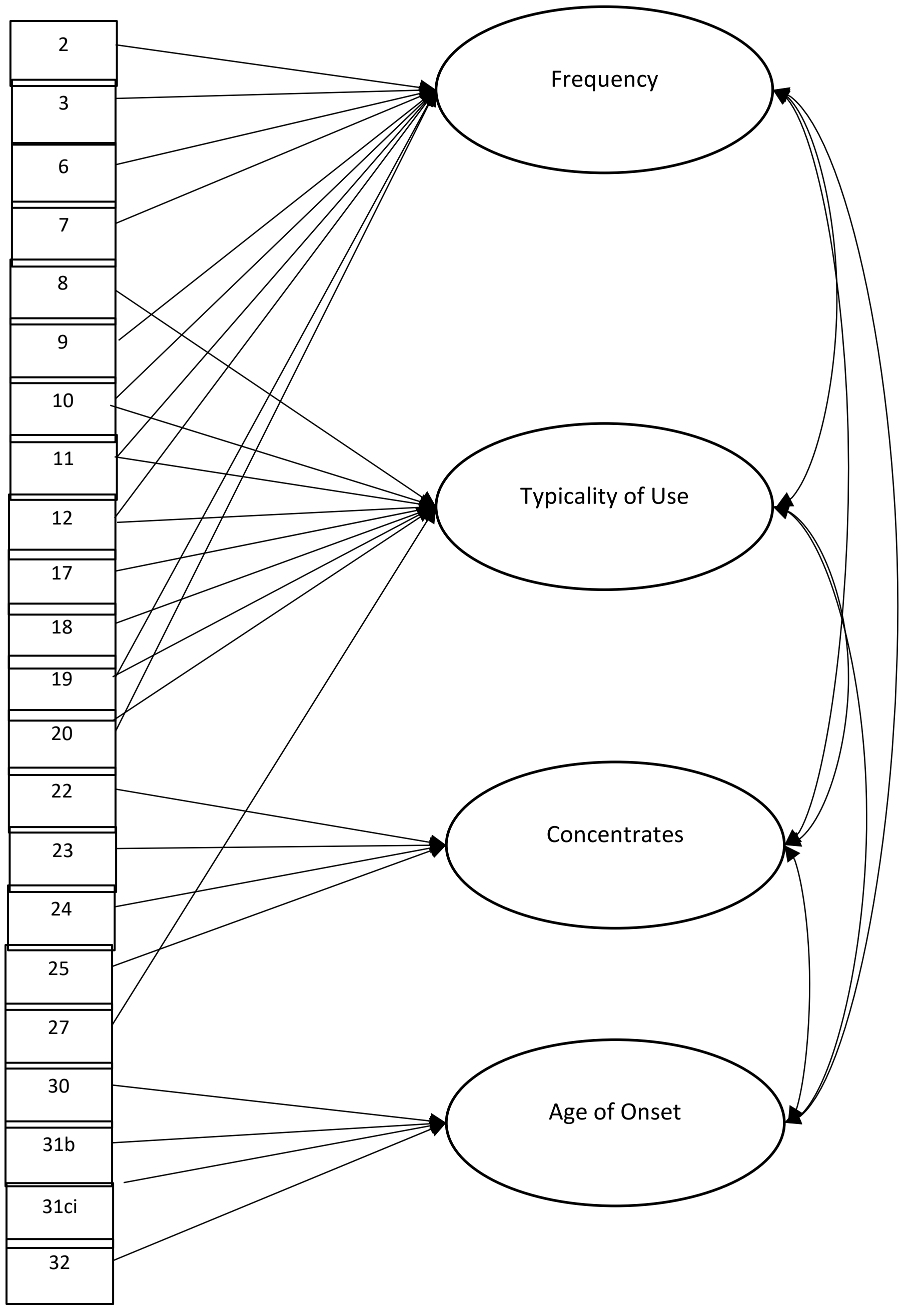
Component Structure of the Hypothesized Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Inventory Modeled as Formative.



Note. All indicators are correlated but not shown. Items were considered to be comprised in a component if they exhibited an eigenvector ≥ .45.

Figure 3

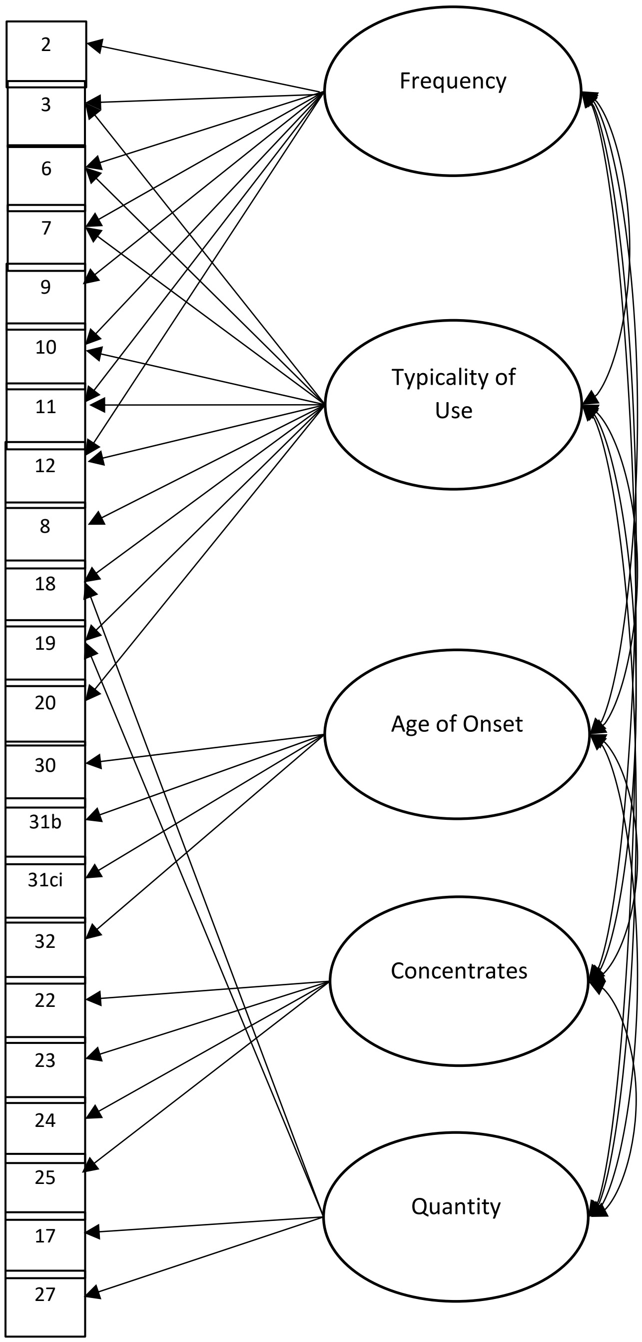
Component Structure of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Inventory Modeled Using Principle Components Analysis.



Note. All indicators are correlated but not shown. Items were considered to be comprised in a component if they exhibited an eigenvector ≥ .45.

Figure 4

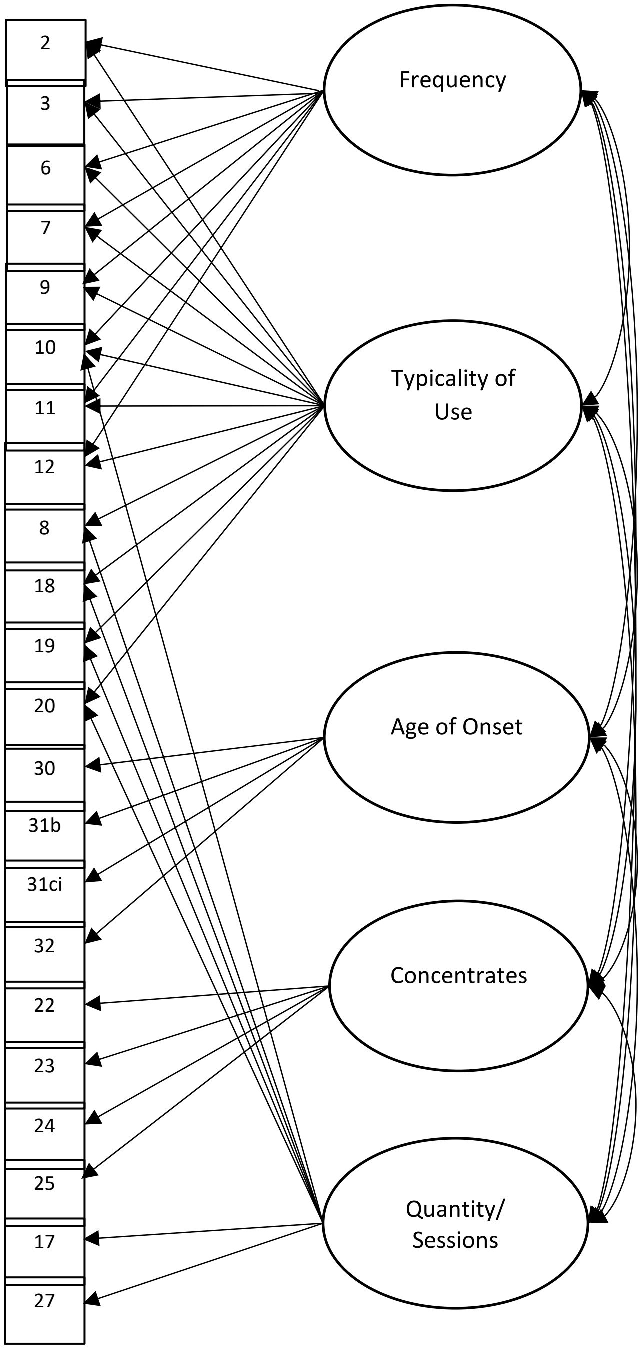
Factor Structure of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Inventory Modeled Using Principle Axis Factoring.



Note. Items were considered to load on a factor if they exhibited a factor loading ≥ .45.

Figure 5

Factor Structure of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Inventory Modeled Using Maximum Likelihood Factor Analysis.



Note. Items were considered to load on a factor if they exhibited a factor loading ≥ .45.

Table 1

Descriptive Responses of the Core Items of the Daily Sessions, Frequency, Age of Onset and Quantity of Cannabis Use Inventory Prior to Transformations.

Multiple Choice Items and Response Options	% Endorsement (N)
2. Which of the following best captures when you last used cannabis?	
Over a year ago	16.5 (73)
9-12 months ago	5.4 (24)
6-9 months ago	5.0 (22)
3-6 months ago	9.3 (41)
1-3 months ago	12.7 (56)
Less than 1 month ago	13.1 (58)
Last week	10.2 (45)
This week	7.7 (34)
Yesterday	12.2 (54)
Today	2.3 (25)
I am currently high	5.7 (25)
3. Which of the following best captures the average frequency you currently use cannabis?	
less than once a year	14.3 (63)
Once a year	12.9 (57)
Once every 2-6 months (2-4 times/yr)	4.5 (20)
Once every 2 months (6 times/yr)	18.3 (81)
Once a month (12 times/yr)	5.7 (25)
2-3 times a month	5.2 (23)
Once a week	10.0 (44)
Twice a week	5.2 (23)
3-4 times a week	9.5 (42)
5-6 times a week	4.5 (20)
Once a day	4.1 (18)
More than once a day	5.9 (26)
6. How many days of the past week did you use cannabis?	
0 days	56.1 (162)
1 day	9.7 (28)
2 days	6.6 (19)
3 days	6.9 (20)
4 days	3.1 (9)
5 days	3.5 (10)
6 days	2.8 (8)
7 days	11.3 (33)
8. Which of the following best captures the number of times you have used cannabis in your entire life?	
1-5 times in my life	14.9 (9.7)
6-10 times in my life	9.0 (26)
11-50 times in my life	20.4 (59)
51-100 times in my life	11.4 (33)
101-500 times in my life	17.6 (51)
501-1000 times in my life	10.7 (31)
1001-2000 times in my life	6.6 (19)
2001-5000 times in my life	4.5 (13)
5001-10,000 times in my life	3.5 (10)
more than 10,000 times in my life	1.4 (4)

Table 1 Continued

Multiple Choice Items and Response Options	% Endorsement (N)
9. Which of the following best captures your pattern of cannabis use throughout the week?	
I do not use cannabis at all	41.3 (183)
I only use cannabis on weekends	27.5 (122)
I only use cannabis on weekdays	0.9 (4)
I use cannabis on weekends and weekdays	30.2 (134)
10. How many hours after waking do you usually first use cannabis?	
I do not use cannabis at all	39.1 (173)
12-18 hours after waking up	17.6 (78)
9-12 hours after waking up	24.2 (107)
6-9 hours after waking up	7.9 (35)
3-6 hours after waking up	4.1 (18)
1-3 hours after waking up	3.4 (15)
Within 1 hour of waking up	1.4 (6)
Within ½ hour of waking up	1.4 (6)
Immediately upon waking up	1.1 (5)
32. Which of the following best captures the average frequency that you used cannabis before the age of 16?	
more than once a day	0.7 (3)
once a day	0.9 (4)
5-6 times a week	0.5 (2)
3-4 times a week	2.3 (10)
twice a week	2.5 (11)
once a week	1.1 (5)
2-3 times a month	4.5 (20)
once a month	3.4 (15)
once every 2 months (6 times/yr)	3.4 (15)
once every 3-6 months (2-4 times/yr)	5.4 (24)
once a year	3.2 (14)
less than once a year	5.2 (23)
Never	66.9 (295)

Free Response Items	Mean (Range)
7. Approximately how many days of the past month did you use cannabis?	7.16 (0.00 – 31.00)
11. How many times a day, on a typical weekday, do you use cannabis?	0.64 (0.00 – 10.00)
12. How many times a day, on a typical weekend, do you use cannabis?	1.13 (0.00 – 15.00)
17. In a typical session, how much marijuana do you personally use? (in grams)	0.69 (0.00 – 16.00)
18. On a typical day you use marijuana, how much do you personally use? (in grams)	0.66 (0.00 – 7.09)
19. In a typical week you use marijuana, how much marijuana do you personally use? (in grams)	2.33 (0.00 – 28.00)
20. On a typical day you use marijuana, how many sessions do you have?	1.18 (0.00 – 8.00)
22. In a typical session you use cannabis concentrates, how many hits do you personally take?	4.07 (0.00 – 30.00)
23. On a typical day you use cannabis concentrates, how many hits do you personally take?	5.20 (0.00 – 100.00)
24. How many hits of cannabis concentrates did you personally take yesterday?	1.65 (0.00 – 100.00)

Table 1 Continued

Free Response Items	Mean (Range)
25. On a typical day you use cannabis concentrates, how many sessions do you have?	1.55 (0.00 – 100.00)
27. When you eat edibles how many milligrams of THC do you personally ingest in a typical session?	75.15 (0.00 – 2000.00)
30. How old were you when you FIRST tried cannabis?	16.25 (12.00 – 21.00)
31b. How old were you when you FIRST started using cannabis regularly (2 or more times per month for 6 months or longer)?	17.29 (13.00 – 22.00)
31ci. How old were you when you FIRST STARTED using cannabis on a daily or near daily basis?	17.30 (14.00 – 21.00)

Table 2

Eigenvectors of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory using Principle Components Analysis

Item	Principal Component			
	Frequency	Age of Onset	Concentrates	Typicality of Use
2. Which of the following best captures when you last used cannabis?	**.92**	-.02	.23	.15
3. Which of the following best captures the average frequency you currently use cannabis?	**.96**	-.10	.12	.17
6. How many days of the past week did you use cannabis?	**.88**	-.03	.24	.23
7. Approximately how many days of the past month did you use cannabis?	**.92**	-.02	.20	.24
8. Which of the following best captures your pattern of cannabis use throughout the week?	.39	-.34	-.13	**.61**
9. Which of the following best captures the number of times you have used cannabis in your entire life?	**.88**	-.10	.05	.07
10. How many hours after waking up do you typically first use cannabis?	**.61**	-.29	.09	**.70**
11. How many times a day, on a typical weekday, do you use cannabis?	**.82**	-.22	.09	**.45**
12. How many times a day, on a typical weekend, do you use cannabis?	**.81**	-.15	.04	**.47**
17. In a typical session, how much marijuana do you personally use?	.06	.04	.15	**.61**
18. On a typical day you use marijuana, how much do you personally use?	.35	-.28	.15	**.93**
19. In a typical week you use marijuana, how much marijuana do you personally use?	**.45**	-.23	.10	**.82**
20. On a typical day you use marijuana, how many sessions do you have?	**.49**	-.37	-.00	**.80**

Table 2 Continued

Item	Principal Component			
	Frequency	Age of Onset	Concentrates	Typicality of Use
23. On a typical day you use cannabis concentrates, how many hits do you personally take?	.05	-.06	**.84**	.12
24. How many hits of cannabis concentrates did you personally take yesterday?	.31	-.06	**.78**	.10
25. On a typical day you use cannabis concentrates, how many sessions do you have?	.11	-.02	**.72**	.15
27. When you eat edibles how many milligrams of THC do you personally ingest in a typical session?	-.25	-.17	.13	**.66**
30. How old were you when you FIRST tried cannabis?	-.32	**.76**	-.10	-.24
31b. How old were you when you FIRST STARTED using cannabis regularly (2 or more times/month)?	-.05	**.89**	-.02	-.33
31ci. How old were you when you FIRST STARTED using cannabis on a daily or near daily basis?	.18	**.80**	-.12	-.08
32. Which of the following best captures the average frequency that you used cannabis before the age of 16?	-.07	**.85**	-.10	-.06

Note. Bold text indicates that the item is included in the component as determined by Eigenvectors ≥ .45.

Table 3

Means, standard deviations, and correlations among the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory Principle Components, Cannabis Consequences, and DSM-5 Cannabis Use Disorder Criteria

	M	*SD*	1	2	3	4	5	6
1. Frequency	-.07	.79	1.00					
2. Typicality of Use	-.11	.67	.90	1.00				
3. Concentrates	-.02	.63	.33	.36	1.00			
4. Age of Onset	.07	.81	-.16	-.25	-.13	1.00		
5. BMACQ	4.12	4.45	.38	.42	.17	-.26	1.00	
6. DSM-5 CUD	1.91	2.60	.39	.43	.15	-.16	.65	1.00

Note. BMACQ = The Brief Marijuana Consequences Questionnaire, CUD = cannabis use disorder symptoms, all correlations are significant at $p < .05$.

Table 4

Reliability Estimates of Principle Components Analysis, Principle Axis Factoring, and Maximum Likelihood Factor Analysis Factors Using the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory

PCA		PAF				MLFA			
Component	α	Factor	α	ω	H	Factor	α	ω	H
Frequency	.94	Frequency	.94	.95	.96	Frequency	.94	.95	.96
Typicality of Use	.91	Typicality of Use	.94	.93	.94	Typicality of Use	.94	.95	.96
Age of Onset	.87	Age of Onset	.86	.88	.92	Age of Onset	.86	.88	.92
Concentrates	.76	Concentrates	.75	.84	.86	Concentrates	.75	.84	.86
		Quantity	.81	.86	.98	Quantity	.87	.86	.92

Note. PCA = principle components analysis, PAF = principle axis factoring, MLFA = maximum likelihood factor analysis. Items were considered part of the component or factor is they exhibited an eigenvector or factor loading ≥.45.

Table 5

Univariate linear regression of Cannabis Consequences on the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory Principle Components, Principle Axis Factoring Factors, and Maximum Likelihood Factor Analysis Factors

	β	S.E.	r^2	p
PCA Component				
Frequency	.38	.04	.14	<.001
Typicality of Use	.42	.04	.17	<.001
Concentrates	.18	.06	.03	.001
Age of Onset	-.26	.04	.07	<.001
PAF Factor				
Frequency	.39	.04	.16	<.001
Typicality of Use	.44	.04	.20	<.001
Concentrates	.20	.06	.04	.002
Age of Onset	-.37	.06	.14	<.001
Quantity	.48	.06	.23	<.001
MLFA Factor				
Frequency	.39	.04	.16	<.001
Typicality of Use	.42	.04	.19	<.001
Concentrates	.20	.06	.04	.002
Age of Onset	-.37	.06	.14	<.001
Quantity	.50	.05	.25	<.001

Note. PCA = principle components analysis, PAF = principle axis factoring, MLFA = maximum likelihood factor analysis.

Table 6

Multivariate regression of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory Principle Components and Cannabis Consequences

Component	β	S.E.	r^2	p
Intercept	1.00	.07	.24	<.001
Frequency	.11	.11		.34
Typicality of Use	.31	.11		.006
Concentrates	.02	.05		.76
Age of Onset	-.17	.05		.001

Table 7

Univariate linear regression of DSM-5 Cannabis Use Disorder Symptoms on the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory Principle Components, Principle Axis Factoring Factors, and Maximum Likelihood Factor Analysis Factors

	β	S.E.	r^2	p
PCA Component				
Frequency	.39	.04	.15	<.001
Typicality of Use	.43	.04	.18	<.001
Concentrates	.16	.06	.03	.003
Age of Onset	-.16	.05	.03	< .001
PAF Factor				
Frequency	.40	.04	.16	<.001
Typicality of Use	.45	.04	.20	<.001
Concentrates	.17	.07	.03	.01
Age of Onset	-.27	.06	.07	<.001
Quantity	.52	.06	.27	<.001
MLFA Factor				
Frequency	.40	.04	.16	<.001
Typicality of Use	.42	.04	.18	<.001
Concentrates	.17	.07	.03	.01
Age of Onset	-.27	.06	.07	<.001
Quantity	.50	.05	.25	<.001

Note. PCA = principle components analysis, PAF = principle axis factoring, MLFA = maximum likelihood factor analysis.

Table 8

Multivariate regression of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory principle Components and DSM-5 Cannabis Use Disorder Symptoms

Component	β	S.E.	r^2	p
Intercept	.78	.06	.24	<.001
Frequency	.10	.11		.35
Typicality of Use	.37	.11		.001
Concentrates	- .01	.05		.87
Age of Onset	-.09	.05		.09

Table 9

Item Loadings of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory using Principle Axis Factoring

	Factor				
Item	Frequency	Typicality of Use	Age of Onset	Concentrates	Quantity
2. Which of the following best captures when you last used cannabis?	**.93**	.44	.03	.28	.07
3. Which of the following best captures the average frequency you currently use cannabis?	**.97**	**.50**	-.05	.18	.04
6. How many days of the past week did you use cannabis?	**.89**	**.47**	.01	.29	.15
7. Approximately how many days of the past month did you use cannabis?	**.93**	**.52**	.04	.26	.12
8. Which of the following best captures the number of times you have used cannabis in your entire life?	.27	**.70**	-.27	-.01	.26
9. Which of the following best captures your pattern of cannabis use throughout the week?	**.90**	.35	-.07	.07	.07
10. How many hours after waking up do you typically first use cannabis?	**.51**	**.83**	-.23	.19	.38
11. How many times a day, on a typical weekday, do you use cannabis?	**.72**	**.79**	-.18	.21	.06
12. How many times a day, on a typical weekend, do you use cannabis?	**.71**	**.77**	-.05	.16	.09
17. In a typical session, how much marijuana do you personally use	.09	.26	-.05	.13	**.81**
18. On a typical day you use marijuana, how much do you personally use?	.28	**.79**	-.28	.22	**.85**
19. In a typical week you use marijuana, how much marijuana do you personally use?	.36	**.80**	-.20	.18	**.62**
20. On a typical day you use marijuana, how many sessions do you have?	.34	**.92**	-.29	.13	.38

Table 9 Continued

	Factor				
Item	Frequency	Typicality of Use	Age of Onset	Concentrates	Quantity
23. On a typical day you use cannabis concentrates, how many hits do you personally take?	.07	.12	-.10	**.85**	.10
24. How many hits of cannabis concentrates did you personally take yesterday?	.36	.10	-.09	**.72**	.21
25. On a typical day you use cannabis concentrates, how many sessions do you have?	.13	.12	-.04	**.65**	.13
27. When you eat edibles how many milligrams of THC do you personally ingest in a typical session?	-.27	.34	-.21	.14	**.58**
30. How old were you when you FIRST tried cannabis?	-.29	-.35	**.72**	-.14	-.23
31b. How old were you when you FIRST STARTED using cannabis regularly (2 or more times/month)?	.03	-.42	**.88**	-.09	-.19
31ci. How old were you when you FIRST STARTED using cannabis on a daily or near daily basis?	.23	-.13	**.79**	-.05	-.01
32. Which of the following best captures the average frequency that you used cannabis before the age of 16?	-.05	-.14	**.84**	-.12	-.12

Note. Bold text indicates that the item loads onto that factor. Factor loadings ≥ .45 loaded onto the factor.

Table 10

Correlations among Factors of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory Using Principle Axis Factoring

Factor	*M*	*SD*	1	2	3	4	5
1. Frequency	-.04	.83	1.00				
2. Typicality of Use	-.11	.71	.97	1.00			
3. Age of Onset	.07	.81	-.15	-.16	1.00		
4. Concentrates	-.02	.63	.29	.33	-.13	1.00	
5. Quantity	-.03	.63	.50	.63	-.22	.68	1.00

Table 11

Item Loadings of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory Using Maximum Likelihood Factor Analysis

	Factor				
Item	Frequency	Typicality of Use	Age of Onset	Concentrates	Quantity
2. Which of the following best captures when you last used cannabis?	**.93**	**.51**	.03	.22	.11
3. Which of the following best captures the average frequency you currently use cannabis?	**.97**	**.59**	-.08	.13	.13
6. How many days of the past week did you use cannabis?	**.91**	**.47**	-.01	.23	.22
7. Approximately how many days of the past month did you use cannabis?	**.94**	**.55**	.00	.21	.22
8. Which of the following best captures the number of times you have used cannabis in your entire life?	.30	**.60**	-.30	-.09	**.52**
9. Which of the following best captures your pattern of cannabis use throughout the week?	**.90**	**.45**	-.06	.03	.08
10. How many hours after waking up do you typically first use cannabis?	**.51**	**.72**	-.32	.08	**.63**
11. How many times a day, on a typical weekday, do you use cannabis?	**.68**	**.89**	-.19	.10	.32
12. How many times a day, on a typical weekend, do you use cannabis?	**.56**	**.90**	-.13	.13	.30
17. In a typical session, how much marijuana do you personally use	.14	.14	-.06	.10	**.53**
18. On a typical day you use marijuana, how much do you personally use?	.14	**.48**	-.37	.10	**1.00**

Table 11 Continued

	Factor				
Item	Frequency	Typicality of Use	Age of Onset	Concentrates	Quantity
20. On a typical day you use marijuana, how many sessions do you have?	.21	**.73**	-.42	.03	**.81**
22. In a typical session you use cannabis concentrates, how many hits do you personally take?	.17	.02	-.04	**.99**	.08
23. On a typical day you use cannabis concentrates, how many hits do you personally take?	.08	.11	-.07	**.84**	.09
24. How many hits of cannabis concentrates did you personally take yesterday?	.37	.06	-.02	**.68**	.18
25. On a typical day you use cannabis concentrates, how many sessions do you have?	.13	.11	.09	**.60**	.16
27. When you eat edibles how many milligrams of THC do you personally ingest in a typical session?	-.18	.08	-.22	.12	**.73**
30. How old were you when you FIRST tried cannabis?	-.25	-.31	**.57**	-.01	-.27
31b. How old were you when you FIRST STARTED using cannabis regularly (2 or more times/month)?	-.01	-.31	**.97**	.04	-.36
31ci. How old were you when you FIRST STARTED using cannabis on a daily or near daily basis?	.17	-.02	**.79**	.00	-.19
32. Which of the following best captures the average frequency that you used cannabis before the age of 16?	-.02	-.17	**.71**	-.01	-.15

Note. Bold text indicates that the item loads onto that factor. Factor loadings ≥ .45 loaded onto the factor.

Table 12

Correlations among Factors of the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory Using Maximum Likelihood Factor Analysis

Factor	*M*	*SD*	1	2	3	4	5
1. Frequency	-.04	.83	1.00				
2. Typicality of Use	-.09	.76	.98	1.00			
3. Age of Onset	.07	.81	-.15	-.20	1.00		
4. Concentrates	-.02	.63	.29	.30	-.13	1.00	
5. Quantity	-.15	.67	.78	.88	-.29	.39	1.00

Table 13

Correlations between Principal Components Analysis Mean Values, Principal Axis Factoring Factor Scores, and Maximum Likelihood Factor Analysis Factor Scores.

Component or Factor	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. PAF Frequency	1.00													
2. PAF Age of Onset	-.15	1.00												
3. PAF Concentrates	.36	-.21	1.00											
4. PAF Typicality of Use	.95	-.20	.39	1.00										
5. PAF Quantity	.57	-.27	.52	.71	1.00									
6. MLFA Frequency	1.00	-.15	.36	.95	.57	1.00								
7. MLFA Age of Onset	-.15	1.00	-.21	-.20	-.27	-.15	1.00							
8. MLFA Concentrates	.36	-.21	1.00	.39	.52	.36	-.21	1.00						
9. MLFA Typicality of Use	.98	-.20	.40	.97	.69	.98	-.20	.40	1.00					
10. MLFA Quantity	.78	-.29	.57	.86	.89	.78	-.29	.57	.87	1.00				
11. PCA Frequency	.99	-.16	.38	.96	.63	.99	-.16	.38	.99	.83	1.00			
12. PCA Age of Onset	-.15	1.00	-.21	-.20	-.27	-.15	1.00	-.21	-.20	-.29	-.16	1.00		
13. PCA Concentrates	.36	-.21	1.00	.39	.52	.36	-.21	1.00	.40	.57	.38	-.21	1.00	
14. PCA Typicality of Use	.85	-.25	.40	.92	.84	.85	-.25	.40	.93	.95	.90	-.25	.40	1.00

Note. PAF = principal axis factoring, MFLA = maximum likelihood factor analysis, PCA = principal components analysis. All correlations are significant at $p < .05$.

Table 14

Correlations between Principal Components Analysis Eigenvector Components, Principal Axis Factoring Factor Scores, and Maximum Likelihood Factor Analysis Factor Scores.

Component or Factor	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. PAF Frequency	1.00													
2. PAF Age of Onset	-.53	1.00												
3. PAF Concentrates	.81	-.56	1.00											
4. PAF Typicality of Use	.95	-.69	.82	1.00										
5. PAF Quantity	.78	-.74	.84	.91	1.00									
6. MLFA Frequency	1.00	-.53	.80	.94	.77	1.00								
7. MLFA Age of Onset	-.60	.99	-.62	-.77	-.80	-.59	1.00							
8. MLFA Concentrates	.70	-.45	.98	.69	.74	.70	-.47	1.00						
9. MLFA Typicality of Use	.97	-.65	.80	1.00	.87	.97	-.73	.68	1.00					
10. MLFA Quantity	.84	-.76	.83	.96	.98	.83	-.82	.70	.93	1.00				
11. PCA Frequency	.74	-.53	.84	.84	.88	.73	-.61	.79	.81	.88	1.00			
12. PCA Age of Onset	-.35	.94	-.43	-.49	-.54	-.35	.90	-.30	-.45	-.55	-.26	1.00		
13. PCA Concentrates	.98	-.46	.87	.91	.83	.97	-.54	.79	.95	.87	.82	-.25	1.00	
14. PCA Typicality of Use	.23	-.53	.40	.40	.68	.22	-.52	.71	.34	.59	.68	-.39	.35	1.00

Note. PAF = principal axis factoring, MFLA = maximum likelihood factor analysis, PCA = principal components analysis. All correlations are significant at $p < .05$.

Chapter 4

Discussion and Conclusions

The present study aimed to evaluate the structure of the DFAQ-CU and the relations between components/factors of the DFAQ-CU and cannabis related problems and CUD symptoms. Results of the current analyses suggest that 1) the modeling techniques (i.e., reflective latent variable modeling compared to formative modeling) result in different structures, highlighting the importance of selecting theoretically appropriate modeling techniques (e.g., Rhemtulla et al., 2020; Borsboom et al., 2003); 2) all models resulted in a different factor or component structure than the original DFAQ-CU (Cuttler & Spradlin, 2017); and 3) attempts to replicate the original facture structure failed to find simple structure.

It was hypothesized that PCA would result in a four component solution comprised of Frequency, Quantity, Age of Onset, and Daily Sessions. Use of PCA did result in four components (i.e., Frequency, Typicality of Use, Age of Onset, and Concentrates) but only two of the components were as hypothesized. The Typicality of Use component speaks to the individuals regular patterns of use (e.g., “How many times a day, on a typical weekday, do you use cannabis?” “On a typical day you use marijuana, how much do you personally use?”). The Frequency component is comprised of items specific to the number of uses in a given time frame (e.g., “How many days of the past week did you use cannabis?”). The Age of Onset component relates to age of first use and age of first regular use (e.g., “How old were you when you FIRST STARTED using cannabis regularly [2 or more times/month]?”). Lastly, the Concentrates component is comprised of items related specifically to the use of cannabis concentrates (e.g., “In a typical session you use cannabis concentrates, how many hits do you personally take?”).

Conceptually, these components seem to be capturing different facets of cannabis use and use patterns. Of note, although the present study applied names to the components, it should be highlighted that components are not latent variables and use of component naming in this context was used to facilitate discussion of outcomes, not to imply causality of manifest items and creation of latent variables (Borsboom, 2006; Fried, 2020).

The Age of Onset and Concentrate components are comparable to Cuttler and Spradlin's (2017) solution. However, the remaining components, though similar in name (e.g., Frequency), are comprised of differing core items. In the PCA solution, it appears that the Typicality of Use component accounts for an individual's typical pattern of use while the Frequency component accounts for frequency in a given timeframe. These two components are distinct in that the Frequency component could capture differences in recent use (e.g., increased used in the past week due to being on vacation). Further, items of the Frequency component are primarily Likert-like items while the Typicality of Use component is comprised primarily of open-response items, which could partially explain relations between items of these components. It warrants noting that the Typicality of Use and Frequency components have a correlation of .90, demonstrating a meaningful amount of overlap between these components. Overall, as hypothesized, modeling the core items as formative resulted in a structure unique from the original reflective solution (Cuttler & Spradlin, 2017). This finding corroborates extant literature that highlights the importance of selecting theoretically appropriate modeling techniques (e.g., Rhemtulla et al., 2020; Borsboom et al., 2003).

Using the components to predict cannabis related problems found that Typicality of Use and Frequency components yielded medium effect sizes. The Concentrates and Age of Onset components yielded small effect sizes. Overall, univariate findings suggest that regularity of use and typical use behaviors are the strongest indicators of cannabis-related problems. This finding mirrors extant literature that has found strong relations between frequency of use and problems (e.g., Hall & Pacula, 2003; Pearson, 2019). Further, this relation makes conceptual sense given that more frequent/regular use likely results in more opportunity to incur negative consequences as a result of use. Results of the multivariate model predicting cannabis problems found that only Typicality of Use and Age of Onset maintain their significance. Again, it is hypothesized that a consistent pattern of regular use yields more opportunity to incur cannabis-related problems. Earlier age of onset is indicative of more total uses (e.g., an individual that began regular use at age 16 likely has more lifetime uses than an individual that began use at age 20; DeWit et al., 2000) and as such, there is increased opportunity to experience negative outcomes. These findings are consistent with extant literature that suggests adolescent onset of use is linked to increased cannabis problems (e.g., Fischer et al., 2010; Richmond-Rakerd, et al., 2016). It appears that frequency of use and concentrate use do not add to our ability to predict who will incur problems when other indicators are considered. Given the overlap in items of the Typicality of Use and Frequency components, the Frequency component does not account for a unique proportion of the variance when Typicality of Use is included. Overall, the multivariate model evinced a large effect size with cannabis use problems, suggesting that the components obtained from core items of the DFAQ-CU are able to account for a large proportion of the variance in cannabis-related problems.

As they relate to CUD symptoms, Typicality of Use and Frequency evinced medium effect sizes and Concentrates and Age of Onset evinced small effect sizes. This suggests that the components of the formative DFAQ-CU are all individually relevant in predicting CUD symptomology. However, in the multivariate model, only Typicality of Use evinced a significant relation, with Age of Onset evincing marginal significance. As with cannabis-related problems, it does not appear that specific concentrate use or frequency of use are uniquely related to CUD symptoms when other indicators are considered. Notably, Typicality of Use evinced the only significant relation with CUD symptoms in the multivariate model, suggesting that the individual's typical use pattern is the strongest single indicator of CUD symptoms. As it relates to assessment in clinical and research settings, it may be better to ask individuals about their typical use pattern (e.g., "on a typical day that you use cannabis…") as opposed to frequency/quantity use in a given time window (e.g., past week or month). It could be that asking about use in a given time window does not account for contextual factors (e.g., vacation, academic variables such as final examinations) that could result in deviations from typical use. Similar to cannabis-related problems, the multivariate model evinced a medium-to-large effect size with CUD symptoms, indicating that the components obtained from the core items of the DFAQ-CU are able to capture a large proportion of the variance in CUD symptoms.

Though it was conceptually argued that the DFAQ-CU should be modeled as formative, the present study aimed to replicate the original factor structure of the DFAQ-CU using reflective modeling (e.g., PAF, MLFA). Both PAF and MLFA resulted in a five-factor solution. However, both models resulted in a high degree of cross-loading (i.e., 8 of 22 items using PAF, 12 of 22 items using MLFA). This suggests that using reflective strategies does not result in simple structure and that items are not distinct to factors using reflective approaches. Using both PAF and MLFA, only the Concentrates and Age of Onset factors resulted in items with no cross-loading (i.e., items with factor loadings ≥ .45 on multiple factors). Ultimately, this pattern of findings suggests that when modeled as reflective, there may be limited distinguishability between items targeting frequency, quantity, and typical patterns of use. Of note, the original DFAQ-CU found correlations between factors ranging from -.16 (age of onset and edible quantity) to .52 (Daily Sessions and Frequency; Cuttler & Spradlin, 2017 p. 8). However, the present work found much higher correlations among factors, with values as high as .97 for the PAF model (Frequency and Typicality of Use) and .98 for the MLFA model (Frequency and Typicality of Use). High correlations between factors further suggest that the factors originating from PAF and MLFA may not be capturing distinct facets of use. Looking at factor loadings, the present PAF model (.47 to .97), MLFA model (.45 to 1.00) and Cuttler and Spradlin's solution (.46 to .94) resulted in wide variability in factor loadings. Further, it warrants acknowledging that though some factors from Cuttler and Spradlin's work have similar names and are comprised of identical manifest variables compared to the factors and components of the current study (e.g., Age of Onset), these factors resulted in different relations with other factors and subsequent outcomes. This is consistent with extant literature highlighting that latent variables thought to be similar across studies can result in discrepant relations with outcomes (e.g., Levin-Aspenson et al., 2020).

Overall, findings of the present study indicate that given the lack of simple structure and distinguishability among factors or components using PCA, PAF, and MLFA, items of the DFAQ-CU may be redundant and use of the original factors (Cuttler & Spradlin, 2017) in outcome studies warrants closer examination. Of note, the present sample was comprised of college students in a location without legalized cannabis as compared to Cuttler and Spradlin's sample of college students in a state with legalized medicinal and recreational cannabis. Further, although both samples were predominately white and female, the present sample had a higher rate of Hispanic/Latinx students whereas the Cuttler & Spradlin sample had higher rates of Asian and Black participants. These contextual and demographic factors may have played a role in differences in factor/component structures and correlations between studies. However, given the arguments in favor of formative modeling strategies, measures aiming to understand cannabis use behaviors should carefully consider modeling approaches during measure development.

Theoretical Implications

The proposed work proffers several implications for future research. Notably, the DFAQ-CU uses a range of items to assess key indicators of cannabis use (e.g., age of onset, frequency, quantity, and daily sessions), making it one of the most comprehensive cannabis use assessments currently available (see Appendix A for further discussion). However, modeling the core items as formative as opposed to reflective resulted in different structures than the original findings (Cuttler & Spradlin, 2017). This highlights the importance of using theoretically grounded data analytic techniques during measure development and evaluation. As previously noted, the core items of the DFAQ-CU are conceptually more likely to be formative (i.e., there is no latent “frequency” variable, rather variables related to frequency of use can be meaningfully reduced). As such, those aiming to develop measures (related to cannabis use behaviors and otherwise) should thoughtfully consider the nature of their variables prior to modeling. As previously discussed, inappropriate modeling techniques can result in inflated item correlations and parameter estimates when formative variables are modeled as reflective which can ultimately result in the overcorrection of “false measurement error,” (Rhemtulla et al., 2020 p. 42). Subsequently, modeling formative variables as latent can result in overestimated relations between factors and later outcomes (e.g., CUD symptoms). As highlighted in the exploratory analyses, findings did suggest differences in effect sizes between PAF and MLFA factors and PCA components as they related to cannabis consequences and CUD symptoms; albeit differences in r^2s ranged from .01 to .07 (see Tables 5 and 7).

Further, attempts to replicate the DFAQ-CU factor structure using reflective modeling techniques (e.g., PAF, MLFA) resulted in a high degree of cross-loading, suggesting that reflective techniques do not result in simple structure and that the latent factors may not be distinct. Though the formative model resulted in four components that were related to the target outcomes (i.e., CUD symptoms, cannabis problems), before research using this measure moves forward, replication is needed. Specifically, it needs to be determined if the formative structure of the DFAQ-CU holds 1) in a sample collected in a different region with different recreational and medical cannabis use laws; and 2) in non-college samples.

As noted, greater accuracy in measuring cannabis use quantity has important health and clinical outcomes as quantity of cannabis use (e.g., quarter grams smoked per month) predicts respiratory and dependence symptoms above and beyond individuals' frequency of use (i.e., days smoked in the past month; Walden & Earlywine, 2008). Replication of the formative structure of the DFAQ-CU could provide evidence that it is a valid and reliable means of assessing of cannabis quantity across modes of administration, which would allow for a more nuanced understanding of the relations between use and health outcomes. Importantly, the DFAQ-CU assesses quantity across a range of methods of administration (e.g., loose leaf, concentrates, edibles). It is relevant to consider method of administration as quantity estimates also differ as a function of method. Among treatment seeking adults, individuals report putting significantly different quantities of cannabis into blunts (mean = .97 grams), joints (mean = .66 grams) and pipes (mean = .39 grams; Mariani et al., 2011), signifying the importance of assessing both estimated quantity and method of administration in studies of cannabis use. Importantly, as previously noted, even moderate-to-heavy cannabis users have difficulty estimating the quantity of their cannabis use (Prince et al., 2018). As such, work relying on self-reported cannabis quantity should be replicated using alternative measurement techniques (e.g., having participants roll a "typical" joint and weighing the amount of cannabis used; Prince et al., 2018) before drawing conclusions on relations between quantity of use and outcomes.

Clinical Implications

It is of clinical importance to understand who is at risk of developing a CUD as CUD has high comorbidity with other psychological disorders and those with a CUD and another comorbid disorder are at increased risk for treatment nonadherence, persistent symptoms, and greater severity of both CUD and other psychiatric symptoms (National Institute on Drug Abuse, 2010). Notably, those meeting criteria for a CUD have higher odds of meeting diagnostic criteria for a mood disorder, posttraumatic stress disorder, anxiety disorders, personality disorders, psychotic disorders, and other substance use disorders as compared to those without a CUD (ORs 1.7 – 14.3; Hasin et al., 2016). Understanding risk factors of CUD development could assist in early prevention and intervention efforts to mitigate complexities of treatment of comorbid diagnoses.

Further, understanding the relations between different indicators of cannabis use (e.g., quantity and frequency) and cannabis use problems allows clinicians and other health professionals to select accurate means of assessment that appropriately weigh the risks associated with different cannabis indicators. For example, Asbridge et al (2014) notes that the ASSIST weighs individuals' frequency of use more strongly than their experiences of use-related problems or quantity of use when determining who is at risk for a cannabis use disorder. Notably, individuals can be qualified as being at "moderate" risk for a CUD if they use cannabis at least once per week but have never experienced any problems as a result of use. However, results of the present study suggest that Typicality of Use, Frequency, Concentrates, and Age of Onset each have a unique effect on the likelihood of CUD development and Typicality of Use evinces the strongest relation with CUD symptoms and cannabis-related problems. As such, multiple indicators should be assessed to gain a more complete understanding of who is at risk for symptom development. Further, as previously discussed, given that the Typicality of Use component evinced the strongest relations with cannabis-related problems and CUD symptoms, it may be more apt for clinicians to assess typical patterns of use rather than asking clients about use in a given time frame.

Limitations and Future Directions

Several limitations of the proposed study warrant discussion. First, the data are cross sectional and as such, causal relations between indicators of cannabis use (e.g., quantity and frequency) and outcomes (CUD symptoms, cannabis-related problems) cannot be assumed. Additionally, college students may evince low endorsement of more severe CUD symptoms and cannabis-related problems as compared to treatment seeking adults, thus limiting our understanding of how indicators of use relate to the more severe items of cannabis-related problems and CUD. Further, despite ensuring participants that survey responses are anonymous, cannabis is an illegal substance in the state of Texas where data were collected, so participants may underreport their cannabis use. Finally, although the DFAQ-CU aims to mitigate several issues with cannabis assessment (e.g., multiple items per indicator; concurrent assessment of quantity, frequency, and age of onset), it still lacks core items pertaining to potency and other key facets of use. In response to the outcomes of this study and in light of the limitations, several future directions for research are offered.

Timing of Daily Sessions

Future work should aim to understand not only the number of smoking sessions per day, but the timing of these sessions. Specifically, among daily users, those that report using cannabis in the morning (i.e., before noon) endorsed using significantly more cannabis per use occasion and endorsed more withdrawal symptoms and cannabis-related problems than those that did not report using cannabis in the morning (Earlywine et al., 2016). Further, the relations between morning use and cannabis withdrawal and problems held after controlling for age, gender, and quantity of use suggesting that morning cannabis users may be at particular risk for adverse consequences. Additionally, college students that use cannabis to sleep report increased frequency of cannabis use as well as increased problems related to use (Drazdowski et al., 2019). Further, consistent with previous findings (e.g.,Babson et al., 2017; Bolla et al., 2008), Drazdowski et al. (2019) also found that increased sleep problems relate to greater frequency of use and more cannabis related problems suggesting that there is a cyclical relation between using cannabis to sleep, cannabis problems and frequency, and sleep problems. Taken in whole, these findings highlight the importance of assessing not only how often individuals engage in cannabis use each day, but when they are using cannabis throughout the day (e.g., before sleep, upon waking) and why.

Potency

Importantly, assessment of cannabis use is lacking in its ability to assess potency of cannabis used. Measuring cannabis potency poses a challenge as potency has demonstrated wide variability (e.g., Gray et al., 2009). Examination of changes in potency over a 10-year period found that cannabis potency varied significantly within any given year (McLaren et al., 2008). Further, these authors note that the potency of cannabis can be affected not only by the compounds of the plant itself, but by the storage of the product (e.g., container, temperature, leaves v. oil), further complicating our ability to measure potency at time of ingestion. Improvement of our ability to assess potency is crucial to understanding nuances of cannabis quantity as it relates to adverse outcomes.

Demographic Differences

Future work should examine differences in relations between cannabis use indicators and cannabis-related factors as a function of demographic variables. For example, Hasin et al. (2016) found that, among the general population, men had 2.2 times greater odds of developing a CUD as compared to women; however Grant et al. (1998) found that, among past year cannabis users, women were particularly vulnerable to the development of cannabis abuse as cannabis quantity increased as compared to men. Examination of racial differences as they relate to CUD found that compared to whites, Hispanics and Asian/Pacific Islanders have decreased odds of developing a CUD but Native Americans have increased risk of CUD development (Hasin et al., 2016). Racial differences have also been identified with regard to preferred method of cannabis administration among users with white participants most commonly using vaporizers or pipes and black participants most commonly using blunts (Streck et al., 2019; Mariani et al., 2011). These differences are important to examine as route of administration has been linked to differences in the intensity and duration of cannabis effects and associated health outcomes (e.g., Vandrey et al., 2017).

Overall, this work suggests that modeling techniques (i.e., reflective, formative) can result in different solutions. As such, model selection should be carefully considered during measure development and in outcome studies. With regard to the DFAQ-CU, three different modeling approaches failed to yield simple structure suggesting that the current DFAQ-CU may be suboptimal for use in cannabis outcome studies in its current form. Further, the use of skip logic questioning, particularly in relation to concentrate use and age of onset, necessitated the use of averages to create component scores as opposed to use of eigenvector multiplication. This highlights the importance of considering modeling techniques during measure development. Presently, the flaws inherent in the assessment (e.g., skip logic) in addition to lack of simple structure suggest that use of modeling techniques, both formative and reflective, may not be suitable for the DFAQ-CU in its current form. The use of individual items may be most appropriate for the time being. However, if the DFAQ-CU were modified to eliminate skip logic and potentially redundant items, use of formative modeling on an updated version of the measure could be appropriate and useful. In relation to cannabis-related consequences and CUD symptoms, individuals' typical use patterns (i.e., typical quantity and frequency of cannabis use) appear most indicative of incurring negative consequences and CUD symptoms. In multivariate models, frequency of use and concentrate use do not significantly add to our ability to predict cannabis consequences or CUD symptom. However, Age of Onset is indicative of consequences, suggesting that earlier age of use may results in higher occurrence of adverse cannabis outcomes.

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Appendices

Appendix A
Extended Literature Review

Self-Report Cannabis Use Assessment

Several means of self-reporting cannabis use have been utilized. However, many of the currently available assessments are suboptimal for garnering an accurate picture of cannabis use behavior. Existing assessments exhibit flaws with regard to assessment of quantity of cannabis use, routes of administration, and accuracy of reporting. For example, many studies use in-house questions to assess cannabis use and although these questions may exhibit face validity, it is difficult to assess their validity and reliability. Further, use of in-house questions limits the ability to compare findings across studies. Other studies have attempted to improve individuals' reporting of their quantity of use by having participants use oregano leaves in rolling papers and pipes to simulate the weight of cannabis consumed (Mariani et al., 2011). Although innovative, this approach has not yet been validated (Norberg et al., 2012). Beyond in-house measures, several measures that have aimed to create a valid and consistent means of assessing cannabis use warrant discussion.

Timeline followback methodology (TLFB; Sobell & Sobell, 1992) is one of the most widely used tools for measuring cannabis use. TLFB consists of presenting participants with a calendar (typically 30 days) and asking them to note on which days they engaged in cannabis use with some forms also asking participants to report the number of joints smoked on use days. Correlations for number of joints, days abstinent, and consecutive use days using the TLFB show adequate reliability with correlations ranging from .70 to .96 (Robinson et al., 2014). Additionally, a metanalytic review of the agreement between TLFB and biological samples (i.e., urine or hair) found agreement rates ranging from 87.3 to 90.5 (Hjorthøj et al., 2012). However, it should be noted that all of the papers reviewed in this meta-analysis were comprised of clinical samples of individuals seeking substance use treatment. As such, these results may not generalize to a nonclinical sample as individuals in treatment may have greater motivation to accurately report their use, particularly as all individuals in these studies knew they were providing biological specimen.

To expand the utility of TLFB to assess quantity of cannabis use, Norberg et al. (2011) used an in-person administration of the TLFB in which participants used the TLFB to report quantity in grams used on each day using *Marijuanilla* (an herb that physically resembles cannabis but does not have psychoactive properties) to create sample joints and pipes to assist in their quantity reporting. Participants were assessed on two occasions spanning 90 days. Interclass correlations (ICC) from time one to time two ranged from .82 to .87, and ICCs for inter-rater reliability were .99, evincing good internal reliability. However, when compared to single-item markers of use (i.e., "over the past 90 days on average, what is the average quantity of your cannabis use?"), ICCs dropped significantly with estimates ranging from .37 to .46. Further, use of the modified TLFB did not add incremental validity over the single item in predicting cannabis use consequences. Taken in whole, this study suggests that TLFB is currently suboptimal for measuring cannabis quantity.

Several additional concerns with the TLFB are worth noting. First, this method is prone to recall bias and requires a high degree of participant demand as it requires participants to accurately recall use over a 30-day period. Though accurate recall may be easy for patterned users (e.g., daily users, weekend-only users), it is likely more difficult for sporadic users (Norberg et al., 2012). Further, current forms of the TLFB have not assessed for different forms of cannabis, routes of administration, THC concentration, nor age of onset, illuminating several gaps in this method of assessment as it pertains to a nuanced understanding of cannabis use patterns (Lopez-Pelayo et al., 2015; Cuttler & Spradlin, 2017).

Another common method of assessment is the use of Likert-like rating scales to assess use across a specified time period (e.g., lifetime, past 30 days). Though Likert-like scales have demonstrated clinical utility and associations with cannabis outcomes, they have not been psychometrically validated in the literature. Further, these scales are often created in-house, significantly decreasing our ability to compare findings across studies and hampering the generalizability of studies. Some studies have attempted to mitigate this concern by pulling their assessment questions from national surveys (e.g., the National Survey on Drug Use and Health). Although doing so may improve consistency across studies, national surveys tend to include few items and are not a comprehensive means of assessing cannabis use behaviors across a range of factors (e.g., quantity, frequency, potency; Cuttler & Spradlin, 2017).

The Marijuana Smoking History Questionnaire (MSHQ; Heishman et al., 2001) is a self-report measure that assesses frequency, quantity, and age of onset of cannabis use. Additionally, the MSHQ assesses multiple means of administration, making it one of the more comprehensive assessments currently available. Though the MSHQ is a more comprehensive measure of cannabis behavior, it has several weaknesses that hamper its utility. Most notably, the MSHQ does not have published scoring procedures and there are no works evaluating its psychometric properties (i.e., validity, reliability, and factor structure). Further, the MSHQ does not provide definitions of key terms such as “regular use” and items are evaluated on a Likert-like scale in which only the endpoints are anchored, which introduces ambiguity in responding. Finally, though the MSHQ contains images to assist participants in reporting quantity of use, the images show little resemblance to joints, again, creating ambiguity.

As cannabis rates increase, assessment of use needs to become more nuanced. Attempts to increase accuracy of cannabis quantity and frequency have posited several solutions. One such example consists of asking participants to report the number of “puffs” and the potency of their cannabis as opposed to joints smoked (Gray et al., 2009). Though this measure may increase accuracy of cannabis quantity reporting for cannabis administered via joint, it fails to assess use via different routes of administration (e.g., bong, edible, concentrate).

Despite attempts to increase the breadth and specificity of cannabis use behaviors, current assessments still fall short of optimal assessment. Lopez-Pelayo and colleagues (2015) reviewed 25 commonly used cannabis assessments (6 cannabis specific scales, 4 drug use scales, 7 structured interviews, and 8 cannabis quantity scales). Their results noted limitations across all assessments such as extensive length, method of administration (e.g., require an interviewer), or lack of psychometric validation. Importantly, most individuals are unable to accurately report the quantity of their cannabis use (Prince et al., 2018). In fact, individuals’ self-reported quantity (.27 grams) was nearly double their actual weight (.14 grams; Norberg et al., 2012), further elucidating the need to develop assessments that enable more accurate and consistent reporting.

Appendix B
Demographics

No.	Question	Coding
1.	How old are you (in years)? Please select from the drop down box.	Ages 18 to 65+
2.	What year are you at TTU?	Freshman ………………………....0 Sophomore ………………………..1 Junior……………………………..2 Senior…………….……………….3
3.	What is your current GPA?	Not sure………………………………0 0-1.5 …………………………………1 1.6-2.0 ………………………………2 2.1-2.5 ………………………………3 2.6-3.0……......................................4 3.1-3.5………………..…………..…5 3.6-4.0………………......................6
4.	What is your major?	Business …………………………..0 Education …………………………1 Psychology………………………..2 Science, Technology, Engineering, Mathematics………………………..3 Fine Arts/Music…………………...4 Other……………………………...5
5.	Are you/were you a member of a sorority or fraternity?	Yes…………………………………0 No, I am not/was not a member, but I regularly attend(ed) sorority/fraternity/greek events……….…………..……….1 No, I am not/was not a member, but I occasionally attend(ed) sorority/greek events………………………………..2 No, I am not/was not a member, and I never attend(ed) sorority/greek events....3 I choose not to answer……….……....4

6.	Where do you live?	Dorm/on-campus housing..……………….0 My family's house or apartment……….1 Off-campus apartment or house……..…..2 Other…………….……………..……………3
7.	Please select your racial/ethnic background. Select all that apply:	African-American or Black…………...1 American Indian or Alaska Native or Indigenous or First Nations…………...2 Arab or Middle Eastern ……………....3 Asian or Asian American……………..4 Hispanic or Latina or Latino…………5 Multiracial or Biracial………………..6 Native Hawaiian or Pacific Islander……7 White or Caucasian or European American……………………………...8 No response or Prefer not to answer…….9
8.	Please describe the group(s) that represents your Hispanic origin or ancestry (e.g., Cuban, Dominican, Mexican).	I am not Hispanic/Latino………………..0 Don't Know……………………………..1 [free response]
C02	What sex were you assigned at birth, on your original birth certificate?	Male……………………………………0 Female……………………………......1 Intersex………………………………....2 Prefer not to respond…………….………...3
	What is your current gender identity?	Female…………………………………..0 Male……………………………………..1 Trans male/Trans man…………………..2 Trans female/Trans woman……………..3 Genderqueer/Gender non-conforming….4 Different identity (please state): _______
	A person's appearance, style, or dress may affect the way people think of them. On average, how do you think people would describe your appearance, style, or dress? (Mark one answer)	Very feminine…………………………...0 Mostly feminine…………………………1 Somewhat feminine……………………..2 Equally feminine and masculine……..…3 Somewhat masculine……………………4 Mostly masculine……………………..…5 Very masculine…………………………6

C08	How do you describe your religion, spiritual practice, or existential worldview? Check all that apply.	Agnostic Animist Atheist Baha'i Buddhist Catholic Christian Deist Hindu Humanist Jewish Lutheran Methodist Pagan Pantheist Polytheist Presbyterian Secular Sikh Spiritual but not religious Taoist Unitarian Universalist Wiccan Other Prefer not to answer No response
C14	In your lifetime, to whom have you been sexually attracted?	Opposite-sex only………………………0 Opposite-sex mostly……………………1 Opposite-sex somewhat…………………2 Both sexes equally………………………3 Same-sex somewhat……………………4 Same-sex mostly………………………5 Same-sex only…………………………6 I have no sexual attractions……………7
C15	In your lifetime, who have you had sex with?	Men only………………………………0 Women only…………………………..1 Both men and women…………………2 I have not had sex…………………….3

	How would you describe your current sexual orientation? Check all that apply.	o Asexual -0 o Bisexual - 1 o Fluid - 2 o Gay - 3 o Heterosexual - 4 o Lesbian - 5 o Pansexual - 6 o Queer - 7 o Questioning - 8 o Prefer not to respond - 9 o Open-response option - 10
C16	What is your current relationship status?	Single/Not Dating…………………...0 Dating Several People…………………1 Dating 1 person exclusively……………2 Engaged………………………………..3 Married…………………..………..4 Partnered, in a Committed Long-term Relationship…………………………….5 Separated from Spouse/Partner……..…6 Divorced………………………………7 Widowed………………..….............8
C17	How long have you been in your current, primary relationship?	Less than 6 months……………….……….0 6 months – 1 year…………..……..……1 1 – 2 years……………………..……...2 2 – 3 years……………………..……3 3 – 5 years……………………..……4 5 or more years…………………..……5 I am currently not in a relationship……6

C18	How much do your parent(s) make in a year (both, or one if you are supported by only one parent)?	0 - $0 - $5,000 1 - $5,000 - $14,999 2 - $15,000 - $24,999 3 - $25,000 - $ $49,999 4 - $50,000 - $74,999 5 - $75,000 - $99,999 6 - $100,000 - $124,999 7 - $125,000 - $149,999 8 - $150,000 - $199,999 9 - $200,000 - $249,999 10 - $250,000 - $299,999 11 - $300,000 - $349,999 12 - $350,000 - $399,999 13 - $400,000 - $449,999 14 - $450,000 - $500,000 15 – greater than $500,000
C19	How many people altogether live on this income (that is, provides at least half of their income)?	Please indicate number of people (free response)
C20	Please choose the option that best describes your father's educational status.	0 - Partial high school 1 - Graduated from high school 2 - Partial college 3 - Associate's Degree 4 - Graduated from college (Bachelor's) 5 - Graduate Degree (ex: Master's, PhD, JD, MD)
C21	Please choose the option that best describes your mother's educational status.	0 - Partial high school 1 - Graduated from high school 2 - Partial college 3 - Associate's Degree 4 - Graduated from college (Bachelor's) 5 - Graduate Degree (ex: Master's, PhD, JD, MD)
C22	Are you a first generation college student?	0 – No 1 – Yes

C23	On average, how much cash, in US dollars, is typically available to you (i.e., checking account, savings account, physical cash)?	

Appendix C
DFAQ-CU Inventory

No.	Question	Coding
1.	Have you ever used cannabis?	0 – No 1 - Yes
2.	Which of the following best captures when you last used cannabis?	1 – Over a year ago 2 - 9-12 months ago 3 – 6-9 months ago 4 – 3-6 months ago 5 – 1-3 months ago 6 – less than 1 month ago 7 – last week 8 – this week 9 – yesterday 10 – today 11 – I am currently high
2b.	How high are you right now?	0 – I am not high at all 1 – I am a little bit high 2 – I am moderately high 3 – I am very high 4 – I am extremely high
3.	Which of the following best captures the average frequency you currently use cannabis?	0 – I do not use cannabis 1 – less than once a year 2 – once a year 3 – once every 2-6 months (2-4 times/yr) 4 – once every 2 months (6 times/yr) 5 – once a month (12 times/yr) 6 – 2-3 times a month 7 – once a week 8 – twice a week 9 – 3-4 times a week 10 – 5-6 times a week 11 – once a day 12 – more than once a day
4.	Which of the following best captures how long you have been using cannabis **at this frequency?**	1 – less than 1 month 2 – 1-3 months 3 – 3-6 months 4 – 6-9 months 5 – 9-12 months 6 – 1-2 years 7 – 2-3 years 8 – 3-5 years 9 – 5-10 years 10 – 10-15 years 11 – 15-20 years 12 – more than 20 years

5.	Before the period of time you indicated above, how frequently did you use cannabis?	0 – I do not use cannabis 1 – less than once a year 2 – once a year 3 – once every 2-6 months (2-4 times/yr) 4 – once every 2 months (6 times/yr) 5 – once a month (12 times/yr) 6 – 2-3 times a month 7 – once a week 8 – twice a week 9 – 3-4 times a week 10 – 5-6 times a week 11 – once a day 12 – more than once a day
6.	How many days of the past week did you use cannabis?	0 – 0 days 1 – 1 day 2 – 2 days 3 – 3 days 4 – 4 days 5 – 5 days 6 – 6 days 7 – 7 days
7.	Approximately how many days of the past month did you use cannabis?	
8.	Which of the following best captures the number of times you have used cannabis in your entire life?	1 – 1-5 times in my life 2 – 6-10 times in my life 3 – 11-50 times in my life 4 – 51-100 times in my life 5 – 101-500 times in my life 6 – 501-1000 times in my life 7 – 1001-2000 times in my life 8 – 2001-5000 times in my life 9 – 5001-10,000 times in my life 10 – more than 10,000 times in my life
9.	Which of the following best captures your pattern of cannabis use throughout the week?	0 – I do not use cannabis at all 1 – I only use cannabis on weekends 2 – I only use cannabis on weekdays 3 – I use cannabis on weekends and weekdays
10.	How many hours after waking do you usually first use cannabis?	0 – I do not use cannabis at all 1 – 12-18 hours after waking up 2 – 9-12 hours after waking up 3 – 6-9 hours after waking up 4 – 3-6 hours after waking up 5 – 1-3 hours after waking up 6 – within 1 hour of waking up 7 – within ½ hour of waking up 8 – immediately upon waking up
11.	How many times a day, on a typical weekday, do you use cannabis?	

12.	How many times a day, on a typical weekend, do you use cannabis?	
13.	What is the primary method you use to ingest cannabis?	0 – I do not use cannabis 1 – Joints 2 – Blunts (cigar sized joints) 3 – Hand pipe 4 – Bong (water pipe) 5 – Hookah 6 – Vaporizer (e.g.,Volcano, Vape pen) 7 – Edibles 8 – Other
14.	Which of the following other methods to ingest cannabis do you use **regularly** (at least 25% of the time you use cannabis)? [Mark all that apply]	0 – None 1 – Joints 2 – Blunts (cigar sized joints) 3 – Hand pipe 4 – Bong (water pipe) 5 – Hookah 6 – Vaporizer (e.g.,Volcano, Vape pen) 7 – Edibles 8 – Other
15.	What is the primary form of cannabis you use?	0 – None A – Marijuana B – Concentrates (e.g.,Oil, Wax, Shatter, Butane, Hash Oil, Dabs) C – Edibles D – Other
16.	What other forms of cannabis do you use **regularly** (at least 25% of the time you use cannabis)? [Mark all that apply]	0 – None A – Marijuana B – Concentrates (e.g.,Oil, Wax, Shatter, Butane, Hash Oil, Dabs) C – Edibles D – Other

Please use the image below to refer to various quantities of marijuana. The image is not to scale; the dollar bill is included to help provide size perspective.

For questions 17 to 19 below, clearly indicate the number of grams of marijuana you use with a number between 0 – 100. Do NOT include other forms of cannabis you may use (such as concentrates). You may use up to 3 decimals to indicate amounts under 1 gram.

Note: 1/8 of a gram = 0.125 grams, ¼ of a gram = 0.25 grams, ½ of a gram = 0.5 grams, ¾ of a gram = 0.75 grams. 1/8 of a ounce = 3.5 grams, ¼ of an ounce = 7 grams, ½ ounce = 14 grams, 1 ounce = 28 grams

17.	In a typical session, how much marijuana do you personally use?	
18.	On a typical day you use marijuana, how much do you personally use?	
19.	In a typical week you use marijuana, how much marijuana do you personally use?	
20.	On a typical day you use marijuana, how many sessions do you have?	
21.	What is the average THC content of the marijuana you typically use? Leave blank if you do not know.	1 – 0-4% 2 – 5-9% 3- 10-14% 4 – 15-19% 5 – 20-24% 6 – 25-30%

		7 – greater than 30%
22.	In a typical session you use cannabis concentrates, how many hits do you personally take?	
23.	On a typical day you use cannabis concentrates, how many hits do you personally take?	
24.	How many hits of cannabis concentrates did you personally take yesterday?	
25.	On a typical day you use cannabis concentrates, how many sessions do you have?	
26.	What is the average THC content of the concentrates you typically use? Leave blank if you do not know.	1 – 0-9% 2 – 10-19% 3 – 20-29% 4 – 30-39% 5 – 40-49% 6 – 50-59% 7 – 60-69% 8 – 70-79% 9 – 80-90% 10 – greater than 90%
27.	When you eat edibles how many milligrams of THC do you personally ingest in a typical session?	
28.	What is your current age?	
29.	How many years in total have you used cannabis?	
30.	How old were you when you FIRST tried cannabis?	
31.	Has there been any time in your life when you used cannabis regularly (2 or more times per month for 6 months or longer)?	0 – No 1 – Yes
31b.	How old were you when you FIRST started using cannabis regularly (2 or more times per month for 6 months or longer)?	
31c.	Has there been a time in your life when you used cannabis on a daily or near daily basis for 6 months or longer?	0 – No 1 – Yes
31ci.	How old were you when you FIRST STARTED using cannabis on a daily or near daily basis?	
32.	Which of the following best captures the average frequency that you used cannabis before the age of 16?	0 – more than once a day 1 – once a day 2 – 5-6 times a week 3 – 3-4 times a week 4 – twice a week 5 – once a week 6 – 2-3 times a month

		7 – once a months 8 – once every 2 months (6 times/yr) 9 – once every 3-6 months (2-4 times/yr) 10 – once a year 11 – less than once a year 12 – never
33.	Do you have a physician's recommendation to use cannabis for medicinal purposes?	0 – No 1 – Yes 2 – Yes, but I use it for both medicinal and recreational purposes
33b.	Which medical condition(s) do you use cannabis for?	
33c.	What percentage of the time do you use cannabis for recreational (rather than medicinal) purposes?	

Appendix D
Brief Marijuana Consequences Questionnaire

INSTRUCTIONS: The following is a list of things that sometimes happen to people either during, or after they have been using marijuana. Select either YES or NO to indicate whether that item describes something that has happened to you IN THE PAST 6 MONTHS.		
1.	The quality of my work or schoolwork has suffered because of my marijuana use.	0 = no 1 = yes
2.	I have driven a car when I was high.	0 = no 1 = yes
3.	I have felt in a fog, sluggish, tired, or dazed the morning after using marijuana.	0 = no 1 = yes
4.	I have been unhappy because of my marijuana use.	0 = no 1 = yes
5.	I have gotten into physical fights because of my marijuana use.	0 = no 1 = yes
6.	I have spent too much time using marijuana.	0 = no 1 = yes
7.	I have felt like I needed a hit of marijuana after I'd gotten up.	0 = no 1 = yes
8.	I have become very rude, obnoxious, or insulting after using marijuana.	0 = no 1 = yes
9.	I have been less physically active because of my marijuana use.	0 = no 1 = yes
10.	I have had trouble sleeping after stopping or cutting down on marijuana use.	0 = no 1 = yes
11.	I have neglected obligations to family, work, or school because of my marijuana use.	0 = no 1 = yes
12.	When using marijuana I have done impulsive things that I regretted later.	0 = no 1 = yes
13.	I have awakened the day after using marijuana and found I could not remember a part of the evening before.	0 = no 1 = yes
14.	I have been overweight because of my marijuana use.	0 = no 1 = yes
15.	I haven't been as sharp mentally because of my marijuana use.	0 = no 1 = yes
16.	I have received a lower grade on an exam or paper than I ordinarily could have because of marijuana use.	0 = no 1 = yes
17.	I have tried to quit using marijuana because I thought I was using too much.	0 = no 1 = yes
18.	I have felt anxious, irritable, lost my appetite or had stomach pains after stopping or cutting down on marijuana use.	0 = no 1 = yes
19.	I often have thought about needing to cut down or to stop using marijuana.	0 = no 1 = yes
20.	I have had less energy or felt tired because of my marijuana use.	0 = no 1 = yes
21.	I have lost motivation to do things because of my marijuana use.	0 = no 1 = yes

Appendix E
Cannabis Use Disorder Criteria (DSM-5)

INSTRUCTIONS: The following is a list of things that sometimes happen to people either during, or after they have been using cannabis. Select either YES or NO to indicate whether that item describes something that has happened to you IN THE PAST 12 MONTHS.		
1.	Cannabis is often taken in larger amounts or over a longer period than was intended.	0 = no 1 = yes
2.	There is a persistent desire or unsuccessful efforts to cut down or control cannabis use.	0 = no 1 = yes
3.	A great deal of time is spent in activities necessary to obtain cannabis, use cannabis, or recover from its effects.	0 = no 1 = yes
4.	Craving, or a strong desire or urge to use cannabis.	0 = no 1 = yes
5.	Recurrent cannabis use resulting in a failure to fulfill major role obligations at work, school, or home.	0 = no 1 = yes
6.	Continued cannabis use despite having persistent or recurrent social or interpersonal problems caused or exacerbated by the effects of cannabis.	0 = no 1 = yes
7.	Important social, occupational, or recreational activities are given up or reduced because of cannabis use.	0 = no 1 = yes
8.	Recurrent cannabis use in situations in which it is physically hazardous.	0 = no 1 = yes
9.	Cannabis use is continued despite knowledge of having a persistent or recurrent physical or psychological problem that is likely to have been caused or exacerbated by cannabis.	0 = no 1 = yes
10.	Tolerance, as defined by either a a. need for markedly increased cannabis to achieve intoxication or desired effect or b. markedly diminished effect with continued use of the same amount of the substance.	0 = no 1 = yes
11.	Withdrawal, as manifested by either a. the characteristic withdrawal syndrome for cannabis b. cannabis is taken to relieve or avoid withdrawal symptoms	0 = no 1 = yes