Are Subjective Effects More Extreme with Higher-Potency Cannabis? A Within-Person Comparison of the Subjective Effects of Marijuana and Butane Hash Oil.

by

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ABSTRACT

Background: Hash oil, a cannabis preparation that contains ultra-high concentrations of tetrahydrocannabinol (THC), is quickly gaining popularity in the United States. Some evidence suggests that hash oil might produce greater intoxication and more severe negative effects than marijuana. This study examined whether the subjective effects of hash oil are more extreme than the subjective effects of marijuana and whether frequency of hash oil use is associated with the subjective effects of marijuana and hash oil. Method: Past-year cannabis users (n = 1,268) were recruited online to complete a questionnaire about the subjective effects of cannabis. Participants who reported past-year use of both hash oil and marijuana (n = 574) rated subjective effects of each type of cannabis in the following positive and negative domains: positive affect, cognitive enhancement, negative affect, cognitive impairment, physiological effects, reduced consciousness, and psychotic-like experiences. Results: Results of within-person comparisons showed that hash oil was rated as producing lesser positive effects (Hash oil: M = 4.53, Marijuana: M = 5.55, t = 14.67, $p < .001$) than marijuana. Negative effects of hash oil were minimal for the full sample (n = 574) and for both frequent and infrequent hash oil users. In general, the frequency of hash oil use was not associated with the subjective effects of marijuana but more frequent hash oil use was associated with rating hash oil as producing greater positive effects ($\beta = 0.28$, t = 6.86, $p < .001$) and lesser negative effects ($\beta = -0.16$, t = -3.83, $p < .001$). Findings were unchanged after controlling for sex, medical cannabis use, and frequency of marijuana use.

Conclusions: Hash oil produced lesser positive effects than marijuana. Negative effects of hash oil were minimal, suggesting that extreme negative effects may be unlikely for experienced cannabis users.

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INTRODUCTION

As of 2019, more than half of U.S. states have legalized cannabis for either medical or recreational purposes. Concomitantly, prevalence rates of cannabis use have increased, with estimates showing that nearly 14% of adults aged 18+ reported cannabis use in 2014 (Carliner et al., 2017). Studies show that the perceived risk of cannabis use is declining (Smart, Caulkins, Kilmer, Davenport, & Midgette, 2017; Miech et al., 2018), but there is speculation that the actual risk of cannabis use may be increasing due to increased cannabis potency (ElSohly et al., 2016; Loflin & Earleywine, 2014; Meier, 2017). Cannabis potency, which is typically judged by the concentration of delta-9-tetrahydrocannabinol (THC; the main psychoactive constituent of cannabis), has increased dramatically from 1995 to 2014 (ElSohly et al., 2016). The increase in cannabis potency is concerning because higher-potency cannabis might cause more severe acute negative or impairing effects, such as psychotic-like experiences, cognitive impairment, and loss of consciousness (Cavazos-Rehg et al., 2016; Chan et al., 2017; Di Forti et al., 2009; D'Souza et al., 2004; Freeman & Winstock, 2015; Quinn, Wilson, Cockshaw, Barkus, & Hides, 2017). Moreover, higher-potency cannabis might result in stronger positive or reinforcing acute effects, such as liking of the drug effect (Chait & Burke, 1994; Freeman & Winstock, 2015), or increased tolerance and withdrawal, all of which drive continued use and increase risk for cannabis use disorder (Freeman & Winstock, 2015; Loflin & Earleywine, 2014; Meier 2017; Pang, Guillot, Zvolensky, Bonn-Miller, & Leventhal, 2017). However, there is little research on the effects of increased cannabis potency on acute responses to cannabis.

Insight into the potentially stronger positive and negative acute effects produced by higher potency cannabis can be gleaned from cannabis administration studies. Numerous studies have administered cannabis with different THC concentrations (e.g., 0.63% vs. 1.95%; Chait & Burke, 1994) to the same people at different times using a standardized smoking procedure (e.g., by controlling number of puffs, puff duration, etc.). Most of these studies have shown that higher potency cannabis produces greater euphoria and stronger physiological effects (Chait & Burke, 1994; Hunault et al., 2008; Hunault et al., 2009). For example, one study found that, compared with lower potency cannabis (0.63% THC), higher potency cannabis (1.95% THC) resulted in higher ratings of liking the drug effect and greater increases in heart rate (Chait & Burke, 1994). Some studies also found that higher potency cannabis produced more severe psychotic-like experiences (e.g., altered perception), negative affect (e.g., anxiety), and cognitive impairment (D'Souza et al., 2004; Hunault et al., 2014), which are generally not associated with decreased likelihood of continued use (Pang et al., 2017).

However, the external validity of cannabis administration studies is limited. For example, cannabis administered in the lab typically has much lower concentrations of THC than cannabis available in the real world (Stith & Vigil, 2016; Vergara et al., 2017). This is because, in the United States, cannabis for research purposes must come from the National Institute on Drug Abuse (NIDA), and cannabis provided by NIDA for cannabis administration studies has, on average, 5.15% THC, which is only 27% of current THC concentrations in recreational markets (e.g., 19.04% THC in Seattle, Washington; Vergara et al., 2017). Only one cannabis administration study compared the acute effects

of cannabis with as high as 23.12% THC to cannabis with no THC (.003% THC), low THC (9.75%), and moderate THC (a 50/50 mix between the 9.75% THC cannabis and the 23.12% THC cannabis) (Hunault et al., 2014). That study found that ratings of liking were highest for the lower-potency cannabis (i.e., 9.75% THC) compared with the no THC cannabis and the moderate- and high-potency cannabis. Moreover, the highest-potency cannabis produced greater negative affect (e.g., feeling down), stronger physiological effects (e.g., dizziness), and self-reported impaired memory (Hunault et al., 2014). These findings are consistent with research suggesting that the reinforcing effects of THC follow an inverted-U-shaped curve such that very low- and very high-potency cannabis are less desirable than medium-potency cannabis (Curran et al., 2016; Hunault et al., 2014; Sanudo-Pena et al., 1997), possibly because the negative effects of high doses of THC counteract any positive effects (Curran et al., 2016; Zernig, Wakonigg, Madlung, Haring, & Saria, 2004; **Figure 1**).

A complementary approach to cannabis administration studies, which have strong internal validity but limited external validity, is observational research comparing reported effects of different cannabis preparations known to vary greatly in average THC content. Two main cannabis preparations that differ in average THC content are marijuana and hash oil. Marijuana (i.e., flower) refers to the dried buds of the cannabis plant and contains, on average, 12 -20% THC (DEA, 2017; ElSohly et al., 2016; Smart et al., 2017; Vergara et al., 2017). Hash oil refers to a highly concentrated extract of cannabis plant material, and contains, on average, 54% THC, but can exceed 80% THC (DEA, 2017; ElSohly et al., 2016; Raber, Elzinga, & Kaplan, 2015; Smart et al., 2017;

Stogner & Miller, 2015). Hash oil is extracted from cannabis plant material using a solvent, such as butane or supercritical carbon dioxide. Hash oil is colloquially referred to as "concentrates" or butane hash oil (BHO), dab, wax, shatter, budder, crumble, or honey oil.

Several observational studies have reported on the acute effects of hash oil. For example, one study collected one month of Twitter data to examine extreme effects of hash oil by randomly selecting 3,540 out of 206,854 tweets containing at least one hash oil-related keyword (e.g., dab, wax, shatter, honey oil, concentrate; Cavazos-Rehg et al., 2016). Twenty-two percent of hash oil-related tweets mentioned extreme effects, which were coded as physiological effects (e.g., passing out/losing consciousness; nausea/vomiting; loss of bodily control), cognitive/psychological effects (e.g., confusion or distorted reality; memory loss), and general (non-specific) effects (e.g., "Took my first dab Tuesday. Almost died."). Of the 22% of hash oil-related tweets mentioning extreme effects, most effects were classified as general effects (non-specific) (46%), 37% were classified as physiological effects, and 17% were classified as cognitive/psychological effects. Thus, when specific extreme effects were reported, most were physiological effects, as opposed to cognitive or psychological effects. However, in a subsequent study of 232 cannabis users aged 18-35 recruited online, almost 36% of participants who used hash oil reported extreme effects, with altered reality/confusion being the most commonly reported extreme effect (23.3%), followed by rapid heartbeat (11.2%), lung pain (9.9%), severe paranoia (6.9%), loss of bodily control (5.2%), and passing out/losing consciousness (3.5%; Cavazos-Rehg, 2018). Thus, these studies suggest that at least

some hash oil users experience extreme negative effects across psychological and physiological domains. However, it is not clear from these studies if effects of hash oil are more extreme than marijuana or if extreme effects of hash oil are more common than extreme effects of marijuana. Thus, a direct comparison of hash oil with marijuana would provide further insight into cannabis potency effects.

We are aware of only one observational study that conducted a within-person comparison of the effects of marijuana and hash oil (Chan et al., 2017). That study was an online survey of 181,870 participants aged 18+ recruited internationally as part of the Global Drug Survey. Analyses compared ratings of the effects of marijuana and butane hash oil (BHO) in 5,676 participants who reported past-year use of both marijuana and BHO. The study, which examined a limited number of effects, found that cannabis users generally reported that BHO caused greater negative effects than marijuana, including reduced ability to function and greater preoccupation/distraction, forgetfulness, restlessness/anxiety, racing thoughts, and hangover effects. Cannabis users also rated hash oil as producing fewer overall pleasurable effects than marijuana. However, if hash oil effects are less positive than marijuana, as suggested by the Global Drug Survey (Chan et al. 2017) and by the inverted U-shaped dose-effect curve (Curran et al., 2016; Hunault et al. 2009), and hash oil effects are more negative than marijuana (Chan et al., 2017; Hunault et al., 2014), it is unclear why people are using hash oil (Carlini, Garrett, & Harwich, 2017; Meacham, Paul, & Ramo, 2018; Smart et al., 2017).

One possibility is that the extent to which marijuana is rated as producing greater positive and lesser negative effects than hash oil differs as a function of previous hash oil

exposure (Hall, 2009). In this case, more frequent hash oil users, who are exposed to the much higher concentrations of THC in hash oil, might have developed greater tolerance to THC than less frequent hash oil users. Drug tolerance could result in a lateral, rightward shift in the inverted U-shaped reward-aversion dose-effect curve. This lateral shift in the inverted U-shaped curve yields two main predictions. First, cannabis users with greater tolerance to THC (frequent hash oil users) will experience less pronounced positive and negative subjective effects of lower-THC cannabis (i.e., marijuana) than cannabis users with lower tolerance to THC (infrequent hash oil users). Second, cannabis users with greater tolerance to THC (frequent hash oil users) will experience more positive and less negative subjective effects of high-THC cannabis (i.e., hash oil) than cannabis users with lower tolerance to THC (infrequent hash oil users), as the negative effects of the higher doses of THC in hash oil might counteract positive effects for cannabis users with lower tolerance to THC (**Figure 2;** Curran et al., 2016**;** Zernig et al., 2004). Thus, previous hash oil exposure could result in the profile of subjective effects of marijuana versus hash oil looking different for frequent and infrequent hash oil users. In support of these predictions, evidence suggests that subjective cannabis effects are less pronounced for regular users (users with high tolerance to THC) than for occasional users (users with lower tolerance to THC) (Colizzi & Bhattacharya, 2018).

The present study had three aims. First, we tested whether the positive and negative subjective effects of cannabis differed for marijuana and hash oil. To test this aim, we conducted within-person comparisons of the self-reported subjective effects of marijuana and hash oil. Within-person comparisons are important because they control

for the effects of background factors, such as sex, race, and genetics, on subjective response. We hypothesized that individuals who used both marijuana and hash oil would rate marijuana as producing greater positive effects and lesser negative effects than hash oil, consistent with the one previous study that conducted within-person comparisons of the subjective effects of marijuana and hash oil (Chan et al., 2017) and consistent with the inverted U-shape reward-aversion dose-effect curve (i.e., medium doses of THC are preferred to high and low doses) (Curran et al., 2016; Hunault et al. 2009). Second, we tested whether the subjective effects of marijuana, and subsequently, the subjective effects of hash oil, differed as a function of frequency of hash oil use. We hypothesized that more frequent hash oil users would have higher tolerance to THC than less frequent hash oil users and would, therefore, rate marijuana as producing lesser positive effects and lesser negative effects as compared with less frequent hash oil users and would rate hash oil as producing greater positive and lesser negative effects as compared with less frequent hash oil users (**Figure 3**). Third, we tested whether the relative difference in subjective response to marijuana versus hash oil would differ for more versus less frequent hash oil users. In terms of positive effects, we hypothesized that the relative difference in effects for marijuana versus hash oil would favor marijuana for infrequent hash oil users (i.e., infrequent hash oil users would rate marijuana more positively than hash oil) and would favor hash oil for frequent hash oil users (i.e., frequent hash oil users would rate hash oil more positively than marijuana). In terms of negative effects, we hypothesized that both frequent and infrequent hash oil users would rate hash oil as producing greater negative effects relative to marijuana but the negative effects of hash

oil relative to marijuana would be more extreme for infrequent hash oil users compared with frequent hash oil users.

This research builds on the single extant study (i.e., Chan et al., 2017) on the subjective effects of marijuana and hash oil by considering a wider range of subjective effects, and by examining how frequency of hash oil use is associated with subjective effects of marijuana and hash oil. We consider subjective cannabis effects in a number of positive and negative effect domains, including positive affect, cognitive enhancement, negative affect, psychotic-like experiences, cognitive impairment, physiological effects, and reduced consciousness. These domains were chosen based on cannabis administration studies and observational studies that have suggested that cannabis acutely affects these domains (Cavazos-Rehg et al., 2016; Chait & Burke, 1994; D'Souza et al., 2004; Hunault et al., 2014; Quinn et al., 2017).

METHOD

Participants

Adult cannabis users were recruited to participate in an anonymous, online survey through various social media outlets (i.e., Reddit, Facebook, Craigslist, Bluelight). Recruitment posts targeted cannabis users through forums and groups focused on recreational and medical cannabis. Eligible participants were past-year cannabis users aged 18 years and older residing in the United States. All participants provided informed consent and were notified that responses for each question were both voluntary and anonymous. Participants who completed the survey were given the option of being entered into a drawing to win one of two $200 Amazon gift cards or one of four $50

Amazon gift cards. To ensure anonymity of survey responses, participants entered the raffle through a separate questionnaire upon survey completion. Precautions were taken to prevent ballot stuffing and ensure one response per participant. A total of 1,249 participants completed the survey. To compare within-person effects of marijuana and hash oil, analyses were limited to the 605 participants (48.44%) who reported past use of both marijuana and hash oil use. Of the 605 participants who reported past use of marijuana and hash oil, n = 31 (5.12%) were excluded due to being flagged for invalid responses (< 75% accuracy on 11 validity questions; **Supplemental Table 1**). Of the 574 remaining participants, the majority were male (n = 318; 55.40%) and Caucasian (Caucasian [n = 428, 74.56%], Hispanic [n = 63, 10.98%], Asian or Pacific Islander [n = 29, 5.05%], African American [n = 17, 2.96%], American Indian or Alaska Native [n = 14, 2.44%], and Other [n = 23, 4.01%]). The mean age of participants was 32.21 (SD = 12.62)**.** This study was approved by the University's Institutional Review Board.

Measures

Cannabis use. Participants were asked questions about their average frequency of both marijuana and butane hash oil use. Butane hash oil was specifically queried because it is the most popular form of hash oil and because it allows for a direct comparison to the previous study comparing subjective effects of marijuana and hash oil (Chan et al., 2017). Questions were taken from the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Scale (DFAQ-CU), which has previously been shown to be reliable and valid (Cuttler & Spradlin, 2017). The DFAQ-CU was adapted to ask about each type of cannabis separately (i.e., marijuana and hash oil). To ensure that participants only

reported on marijuana, and subsequently, only reported on hash oil, questions were prefaced with directions to report only on the one form of cannabis (marijuana or hash oil) and written directions were accompanied by images of each type of cannabis (**Figure 4**). Participants were asked "Which of the following best captures the average frequency you currently use [marijuana, butane hash oil]?" Response options ranged from 1 (less than once a year) to 12 (more than once a day). Participants were then asked, "Which of the following best captures how long you have been using [marijuana, butane hash oil] at this frequency?" Response items ranged from 1 (less than one month) to 12 (more than 20 years).

Subjective cannabis effects. Subjective cannabis effects were asked separately for marijuana and hash oil, with directions to report only on marijuana and, subsequently, to report only on hash oil. To ensure accurate reporting, questions were accompanied by pictures of each form of cannabis (**Figure 4**). Questions about subjective cannabis effects were taken from several different sources, including the Global Drug Survey (Chan et al., 2017), the Twitter study of hash oil effects (Cavazos-Rehg et al., 2016), the Cannabis Experiences Questionnaire – Intoxication Effects Checklist (CEQ-I; Quinn et al., 2017), and previous visual analog scales used in cannabis administration studies (e.g., Hunault et al., 2014). When items from different studies overlapped substantially or were identical (e.g., 'Anxious' from Quinn et al., 2017 and 'Anxious' from Chan et al., 2017), only one item was selected for inclusion in the survey. Items were selected with the aim of understanding positive and negative effects of both marijuana and hash oil. Positive effects were examined in two domains: positive affect and cognitive enhancement.

Positive affect was further split into a low arousal (e.g., relaxed) and a high arousal (e.g., excited) scale as cannabis research indicates that low arousal cannabis effects are more commonly reported than high arousal effects (Zeiger et al., 2010). Negative effects were examined in five domains: negative affect, cognitive impairment, psychotic-like experiences, physiological effects, and reduced consciousness. As with positive affect, negative affect was split into a low arousal (e.g., depressed) and a high arousal (e.g., anxious) scale. Response options ranged from 0 to 10 (not at all [0] to extremely [10] or never [0] to always [10]). Scale items were averaged to create a total score for each subjective effect scale. **Table 1** shows items (with sources) used to assess each domain. Internal consistency was good for both positive effect domains and negative effect domains for marijuana (total positive effects [$\alpha = 0.88$], positive affect – low arousal [$\alpha = 0.81$], positive affect – high arousal [$\alpha = 0.74$], cognitive enhancement [$\alpha = 0.85$], total negative effects [$\alpha = 0.95$], negative affect – low arousal [$\alpha = 0.83$], negative affect – high arousal [$\alpha = 0.84$], psychotic-like experiences [$\alpha = 0.86$], cognitive impairment [$\alpha = 0.73$], physiological effects [$\alpha = 0.78$], and reduced consciousness [$\alpha = 0.78$]) and for hash oil (total positive effects [$\alpha = 0.93$], positive affect – low arousal [$\alpha = 0.87$], positive affect – high arousal [$\alpha = 0.84$], cognitive enhancement [$\alpha = 0.91$], total negative effects [$\alpha = 0.96$], negative affect – low arousal [$\alpha = 0.86$], negative affect – high arousal [$\alpha = 0.88$], psychotic-like experiences [$\alpha = 0.87$], cognitive impairment [$\alpha = 0.81$], physiological effects [$\alpha = 0.82$], and reduced consciousness [$\alpha = 0.75$]). Participants received a total score for each scale if they responded to at least 75% of items in that scale. For example, participants received a low arousal positive affect score if they

responded to at least three out of four low arousal positive affect scale items. Of the 574 participants, n = 534 (93.03%) had total scores computed for all 22 subjective effect scales (i.e., subjective scales for both marijuana and hash oil including total positive effects, low arousal positive affect, high arousal positive affect, cognitive enhancement, total negative effects, low arousal negative affect, high arousal negative affect, psychotic-like experiences, cognitive impairment, physiological effects, and reduced consciousness). The remaining 40 participants had total scores computed for at least one subjective effect scale with the majority of these remaining participants (n = 31) having total scores computed for at least half (i.e., 11 out of 22) of the subjective effect scales. Total scores for each domain were log-transformed prior to statistical testing due to the skewed distribution of the data.

Statistical Analyses

To compare subjective effects of marijuana and hash oil within individuals, we used paired t-tests. To test whether the subjective effects of marijuana, and subsequently the subjective effects of hash oil, were associated with frequency of current hash oil use, we regressed subjective effects of marijuana, and subsequently subjective effects of hash oil, on frequency of current hash oil use, controlling for sex, medical cannabis use, and current frequency of marijuana use. To test whether relative differences in the subjective effects of marijuana versus hash oil were associated with frequency of current hash oil use, we computed difference scores representing the difference in each person's rating of the subjective effect of marijuana versus hash oil (e.g., marijuana positive effect scale minus hash oil positive effect scale). Then we regressed that difference score on current

frequency of hash oil use, controlling for sex, medical cannabis use, and current frequency of marijuana use.

RESULTS

Sample Characteristics

Table 2 shows characteristics for the full sample of participants (n = 574) who reported use of both marijuana and hash oil. In the full sample, marijuana use was frequent, with an average frequency of use of approximately five to six times per week (corresponding to M = 10.07, SD = 2.69). Hash oil use was less frequent, with an average frequency of use of nearly two to three times per month (corresponding to M = 5.63, SD = 3.78). To elucidate the demographic and cannabis use correlates of more frequent hash oil use, characteristics are shown for frequent and infrequent hash oil users separately (**Table 2**). Groups were based on a median split. Frequent hash oil users were more likely to be male (61.83% frequent hash oil users vs. 50.00% infrequent hash oil users, χ^2 = 8.39, p = .02) and to have a medical marijuana card (41.98% frequent hash oil users vs. 25.64% infrequent hash oil users, χ^2 = 17.18, p < .001) than infrequent hash oil users. This finding is consistent with some research suggesting that men (Daniulaitye et al., 2017) and medical cannabis cardholders (Lankenau et al., 2017) are more likely to use hash oil than women and cannabis users who do not have a medical cannabis card. The two groups (i.e., frequent and infrequent hash oil users) did not differ in terms of frequency of marijuana use (frequent hash oil users: M = 10.18, SD = 2.59; infrequent hash oil users: M = 9.98, SD = 2.77; t (572) = -0.88, p = .38).

Within-person Comparison of the Subjective Effects of Marijuana and Hash Oil

We conducted within-person comparisons to test whether positive and negative subjective effects differed for marijuana and hash oil. We hypothesized that individuals who used both marijuana and hash oil would rate marijuana as producing greater positive effects and lesser negative effects than hash oil. Results were somewhat consistent with hypotheses (**Table 3**). Consistent with hypotheses, marijuana was rated as producing greater total positive effects than hash oil (marijuana positive effects total: $M = 5.55$, SD = 1.70; hash oil positive effects total: $M = 4.53$, SD = 2.13; *paired* $t = 14.67$, $p < .001$). Inconsistent with hypotheses, total negative effects did not differ between marijuana and hash oil (marijuana negative effects total: $M = 1.37$, SD = 1.09; hash oil negative effects total: $M = 1.41$, SD = 1.30; *paired* $t = 1.63$, $p = 0.10$). Notably, however, marijuana was rated as producing lesser physiological effects and a lower likelihood of causing reduced consciousness than hash oil but greater negative affect (both low and high arousal negative affect), psychotic-like experiences, and cognitive impairment relative to hash oil (**Table 3**). However, means for negative effects were quite small, indicating that negative effects of both marijuana and hash oil are mild or infrequent. Thus, the main difference between marijuana and hash oil, as indicated by effect sizes, was that marijuana produces more positive effects than hash oil.

Subjective Effects of Marijuana and Hash Oil as a Function of Frequency of Hash Oil Use

To ascertain if ratings of the subjective effects of marijuana and hash oil differed as a function of frequency of hash oil use, each subjective effect was regressed on frequency of hash oil use, and the results of these statistical tests are reported in **Table 4**.

To aid interpretation of statistical tests, we report mean subjective effect ratings for frequent and infrequent hash oil users (with groups based on a median split). We hypothesized that frequent hash oil users would rate marijuana as producing lesser positive and negative effects than infrequent hash oil users. Contrary to hypotheses, results showed that frequency of hash oil use was unrelated to the positive effects of marijuana (β = -0.00, t = -0.08, p = 0.94). However, consistent with hypotheses, greater frequency of hash oil use was associated with marijuana producing lesser total negative effects (β = -0.12, t = -2.81, p = 0.01). In general, however, frequency of hash oil use was not statistically significantly associated with the negative effect scales, including low arousal negative affect, psychotic-like experiences, physiological effects, and reduced consciousness. The exceptions were that more frequent hash oil use was associated with rating marijuana as producing lesser high arousal negative affect and lesser cognitive impairment. After additionally controlling for sex, medical cannabis use, and frequency of marijuana use, frequency of hash oil use was only significantly related to rating marijuana as having lesser high arousal negative affect.

We then tested whether the subjective effects of hash oil would differ as a function of frequency of hash oil use (**Table 4**). We hypothesized that frequent hash oil users would rate the subjective effects of hash oil as producing greater positive effects and lesser negative effects than infrequent hash oil users. Findings supported these hypotheses. Analyses revealed that more frequent hash oil use was associated with higher ratings of the positive effects of hash oil and lower ratings of the negative effects of hash oil. For example, the results of a regression showed that as frequency of hash oil use

increased, hash oil was rated as producing greater total positive effects (β = 0.28, t = 6.86, p = < .001). The means for the total positive effects of hash oil for frequent and infrequent users also illustrate this. Frequent hash oil users rated the total positive effects of hash oil as higher (M = 5.00, SD = 1.96, range 0 to 10) than infrequent hash oil users (M = 4.14, SD = 2.18). These findings were generally unchanged after additionally controlling for sex, medical cannabis use, and frequency of marijuana use.

Within-Person Difference Ratings for Marijuana and Hash Oil as a Function of Frequency of Hash Oil Use

Table 5 shows a test of whether the relative difference in the subjective response to marijuana versus hash oil differed as a function of frequency of hash oil use. We first computed the difference in ratings for marijuana versus hash oil (e.g., marijuana positive effect minus hash oil positive effect). To ascertain if difference scores differed as a function of frequency of hash oil use, each subjective effect difference score was regressed on frequency of hash oil use. The results of these statistical tests are reported in the shaded columns of **Table 5**. To aid interpretation of statistical tests of the association between difference scores and frequency of hash oil use, we report within-person means on the subjective effect scales for marijuana and hash oil for both frequent and infrequent hash oil users (with groups based on a median split). We hypothesized that frequent hash oil users would rate marijuana less positively than hash oil (i.e., the difference score for positive effects of marijuana minus hash oil would be negative) and, conversely, that infrequent hash oil users would rate marijuana more positively than hash oil (i.e., the difference score for positive effects of marijuana minus hash oil would be positive).

However, analyses revealed that both frequent and infrequent hash oil users rated marijuana as producing greater positive effects than hash oil. Nonetheless, the extent to which marijuana was rated as producing greater positive effects was attenuated for frequent hash oil users compared with infrequent hash oil users. For example, results of a regression analysis showed that more frequent hash oil use was associated with a smaller difference in the extent to which marijuana was rated as producing greater total positive effects (range 0 to 10) than hash oil (β = -0.37, t = 9.53, p = < .001). The means show this pattern clearly. For example, frequent hash oil users rated the difference in total positive effects between marijuana and hash oil as less extreme (Marijuana: M = 5.49, Hash oil: M = 5.00, Difference [marijuana minus hash oil]: 0.49) than infrequent hash oil users (Marijuana: M = 5.61, Hash oil: M = 4.14, Difference [marijuana minus hash oil]: 1.47). These findings were generally unchanged after additionally controlling for sex, medical cannabis use, and frequency of marijuana use.

We also hypothesized that both frequent and infrequent hash oil users would rate marijuana as producing lesser negative effects than hash oil, but that this difference would be attenuated for frequent hash oil users. Results were somewhat consistent with this hypothesis. For example, consistent with this hypothesis, both frequent and infrequent hash oil users rated marijuana as producing lesser physiological effects than hash oil, and the extent to which marijuana was rated as producing lesser physiological effects was attenuated for frequent hash oil users. A similar pattern was also observed for reduced consciousness. However, contrary to hypotheses, a different pattern of results was found for both high arousal negative affect and cognitive impairment. In terms of

high arousal negative affect, both frequent and infrequent hash oil users rated marijuana as producing higher levels of negative affect than hash oil. Surprisingly, the extent to which marijuana was rated as producing greater high arousal negative affect was actually more extreme for frequent hash oil users compared with infrequent hash oil users. In terms of cognitive impairment, frequent hash oil users rated marijuana as producing more cognitive impairment than hash oil and, conversely, less frequent hash oil users rated marijuana as producing less cognitive impairment than hash oil. Results were generally unchanged after additionally controlling for sex, medical cannabis use, and frequency of marijuana use.

DISCUSSION

The purpose of this study was to compare the positive and negative subjective effects of two types of cannabis known to vary in average THC content: marijuana and hash oil. We hypothesized that lower THC cannabis (i.e., marijuana) would be rated as producing greater positive effects and lesser negative effects than higher THC cannabis (i.e., hash oil), consistent with research demonstrating that the reinforcing effects of THC follow an inverted U-shaped curve whereby medium doses of THC are preferred to high and low doses of THC (Curran et al., 2016, Hunault et al., 2014). Findings showed that marijuana was rated as producing greater positive effects and lesser physiological effects than hash oil, consistent with hypotheses. However, marijuana was also rated as producing worse negative affect and cognitive impairment than hash oil. In general, though, reports of negative effects of both marijuana and hash oil were minimal, suggesting that the main difference in the subjective effects of marijuana and hash oil was

in terms of their positive effects, with marijuana producing greater positive effects than hash oil.

The present study also examined whether subjective cannabis effects differed as a function of frequency of hash oil use. Past research suggests that frequent cannabis users develop tolerance to the subjective effects of cannabis (Colizzi & Battachary, 2018). This increased tolerance might shift the inverted U-shaped reward-aversion curve to the right (**Figure 2**; Zernig et al., 2004). That is, at high THC concentrations, frequent hash oil users might experience more positive and less negative effects than infrequent hash oil users, who have not developed as high of a tolerance and might find such high doses of THC to be aversive (**Figure 2**). Therefore, we hypothesized that frequent hash oil users would experience lesser positive and lesser negative effects of marijuana than infrequent hash oil users. Findings revealed that frequency of hash oil use was not statistically significantly associated with the subjective effects of marijuana. We also hypothesized that frequent hash oil users would experience greater positive effects and lesser negative effects of hash oil than infrequent hash oil users. Findings from analyses comparing frequent vs. infrequent hash oil users on ratings of hash oil were generally consistent with hypotheses (**Table 4**).

We also hypothesized that higher tolerance among frequent hash oil users would result in frequent hash oil users experiencing more positive effects for hash oil than for marijuana and, conversely, infrequent hash oil users experiencing more positive effects for marijuana than for hash oil. Contrary to this hypothesis, however, both frequent and infrequent hash oil users rated marijuana more positively than hash oil. Moreover, we

hypothesized that both frequent and infrequent hash oil users would rate hash oil as having greater negative effects than marijuana, but we found that, at least for some effects, both frequent and infrequent hash oil users rated marijuana more negatively than hash oil. It is unclear why frequent hash oil users, who presumably have developed tolerance to the lower doses of THC in marijuana, would rate marijuana (which has a lower concentration of THC) as producing greater positive effects and in some cases greater negative effects (e.g., worse cognitive impairment) than hash oil (which has a higher concentration of THC), but we can think of several possible explanations.

One possible explanation is that THC alone might not underlie subjective effect ratings. Although THC is the main psychoactive constituent of cannabis, research has found that blood THC concentrations correlate only moderately with subjective drug effects, indicating that there are factors other than THC associated with subjective cannabis effects (Spindle et al., 2018). There are several hundred other chemical constituents (e.g., cannabinoids, terpenoids, flavonoids) that might contribute to subjective effects of cannabis (Ahmed et al., 2015; Aizpurua-Olaizola et al., 2016; ElSohly & Slade, 2005). The distribution of these chemical constituents might differ for marijuana and hash oil, because of the way marijuana and hash oil are prepared (Sexton, Shelton, Haley, and West, 2018). For example, terpenes, which produce the flavor and scent of cannabis, and which might also have anti-anxiety, anti-depressant, and anti-nociceptive properties, are often lost in the hash-oil extraction process (Sexton et al., 2018). However, this might then suggest that marijuana would be rated as producing less negative affect than hash oil, and this was not the case. Alternatively, various methods of

consuming cannabis, such as smoking or vaping, might be associated with differences in subjective effects (Spindle et al., 2018). There is also some research to suggest that smoking marijuana might be preferred because it is associated with both a tradition and a ritual (Murphy et al., 2015), whereas vaping either marijuana or hash oil might not reproduce that sense of either tradition. However, these explanations again could not explain the profile of findings where marijuana is rated as more extreme on only some effects.

A second possible explanation is that frequent hash oil users titrate their use of hash oil (take smaller quantities when THC content is high) to the point that they actually receive lower doses of THC from hash oil than from marijuana. If frequent hash oil users are titrating their use of hash oil to the point that they are receiving lower doses of THC from hash oil than from marijuana, frequent hash oil users would rate marijuana as producing stronger positive and negative effects relative to hash oil. Notably, titration cannot fully explain the current pattern of findings as both frequent and infrequent hash oil users rated marijuana as producing lesser subjective effects in some outcomes (i.e., physiological effects and reduced consciousness) when compared with hash oil. Thus, the most likely answer is that there is a complex interplay between several factors, including constituents of marijuana and hash oil, method of use, and quantity of cannabis used that might help explain why both frequent and infrequent hash oil users rated lower THC cannabis (i.e., marijuana) as producing greater positive and negative effects than high-THC cannabis (i.e., hash oil).

The present study has several limitations. First, blood levels of THC, and factors that affect blood levels of THC, such as the actual THC concentration in both marijuana and hash oil and the amount of marijuana and hash oil typically used, were not directly assessed. Notably, however, research shows that, on average, hash oil contains three times as much THC as marijuana (ElSohly et al., 2014; Smart et al., 2017). There is also research to show that cannabis users receive higher doses of THC when using higher potency cannabis even when they attempt to titrate their dose (van der pol et al., 2014; Freeman et al., 2014). Nevertheless, blood tests of THC and cannabinoid content testing would help elucidate whether THC underlies the subjective effect ratings for cannabis and determine whether individuals successfully titrate their dose of THC, by taking lower quantities of hash oil than marijuana. Second, this is a cross-sectional study, and so we could not assess whether there were changes in subjective cannabis effects as frequency of hash oil use increased. Longitudinal studies will be needed to address this matter. Third, these effects might better reflect expectancies rather than in-the-moment subjective effects. Placebo-controlled cannabis administration studies could provide further insight into in-the-moment subjective effects. However, federal law in the United States mandates that cannabis for research purposes must come from NIDA, and currently NIDA does not provide cannabis with THC concentrations as high as the THC concentrations found in hash oil (Stith & Vigil, 2016; Vergara et al., 2017). Fourth, in general, our participants were frequent marijuana users, who used marijuana, on average five to six times per week. Therefore, findings might not generalize to novice users (Miller, Stogner, & Miller, 2015). Fifth, we specifically focused on butane hash oil,

which is the product of only one of many extraction techniques that produces hash oil. However, other extraction techniques are less common and produce similar products with similar THC concentrations (Stogner & Miller, 2015). Finally, we did not assess use of other cannabis preparations, such as hash and kief. These types of cannabis preparations are considered cannabis concentrates and have, on average, THC concentrations that are between the THC concentrations of marijuana and hash oil (ElSohly et al., 2016).

The present study contributes to the literature by providing insight into a broader range of positive and negative subjective effects of both marijuana and hash oil. In addition, this is the only extant study that has examined whether subjective cannabis effects differ for frequent and infrequent hash oil users. This study found that, in general, marijuana was rated as producing greater positive effects than hash oil. Negative effects for hash oil were quite minimal suggesting that, at least for experienced cannabis users, extreme negative subjective effects of hash oil are not likely. The present study also suggests that there are likely several factors, besides THC content of the cannabis, that relate to subjective cannabis effects. Future research on subjective effects of marijuana and hash oil could benefit from assessment of blood levels of THC, quantity of marijuana and hash oil use, route of administration, other cannabinoids, and terpenes.

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Table 1. Subjective Effect Domains

Item	Source
Positive Effects Scale	
Positive Affect - Low Arousal	
To what extent does [marijuana/butane hash oil] cause you to:	
Feel happy (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel laid back (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel pleasant (Not at all [0] to Extremely [10])	Chan et al., 2017
Feel relaxed (Not at all [0] to Extremely [10])	Chan et al., 2017
Positive Affect - High Arousal	
To what extent does [marijuana/butane hash oil] cause you to:	
Feel ecstatic (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel energized (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel excited (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel giggly (Not at all [0] to Extremely [10])	Quinn et al., 2017
Look for excitement (Not at all [0] to Extremely [10])	Quinn et al., 2017
Cognitive Enhancement	
To what extent does [marijuana/butane hash oil] cause you to:	
Feel detail-oriented (Not at all [0] to Extremely [10])	
Feel full of ideas (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel full of plans (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel motivated (Not at all [0] to Extremely [10])	Zuurman et al., 2008
Feel more creative (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel able to understand the world better (Not at all [0] to Extremely [10])	Quinn et al., 2017
Negative Effects Scale	
Negative Affect – Low Arousal	
To what extent does [marijuana/butane hash oil] cause you to feel:	
Depressed (Not at all [0] to Extremely [10])	Quinn et al., 2017
Sad (Not at all [0] to Extremely [10])	Quinn et al., 2017
Negative Affect – High Arousal	
To what extent does [marijuana/butane hash oil] cause you to feel:	
Anxious (Not at all [0] to Extremely [10])	Chan et al., 2017; Quinn et al., 2017
Nervy (Not at all [0] to Extremely [10])	Quinn et al., 2017
Panicked (Not at all [0] to Extremely [10])	Cavazos-Rehg et al., 2016
Restless (Not at all [0] to Extremely [10])	Chan et al., 2017
Worried that others are looking at or talking about you (Not at all [0] to Extremely [10])	Chan et al., 2017

Table 1. Continued.

Psychotic-like Experiences Scale	
To what extent does [marijuana/butane hash oil] cause you to:	
Change how you see, feel, or hear things (Not at all [0] to Extremely [10])	Chan et al., 2017
Feel fearful that you are going crazy (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel like you no longer know yourself (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel threatened by an unknown source (Not at all [0] to Extremely [10])	Quinn et al., 2017
Have out of body experiences (Not at all [0] to Extremely [10])	Quinn et al., 2017
Have visions (Not at all [0] to Extremely [10])	Quinn et al., 2017
Hear things other people couldn't hear (Not at all [0] to Extremely [10])	Quinn et al., 2017
Lose sense of reality (Not at all [0] to Extremely [10])	Quinn et al., 2017
Cognitive Impairment Scale	
To what extent does [marijuana/butane hash oil] cause you to feel:	
Disturbed in your thinking (Not at all [0] to Extremely [10])	Quinn et al., 2017
Forgetful (Not at all [0] to Extremely [10])	Chan et al., 2017
Like it impairs your ability to talk comfortably (Not at all [0] to Extremely [10])	Chan et al., 2017
Like your thoughts are racing (Not at all [0] to Extremely [10])	Chan et al., 2017; Quinn et al., 2017
Preoccupied or distracted (Not at all [0] to Extremely [10])	Chan et al., 2017
Physiological Effects Scale	
How often does [marijuana/butane hash oil] cause you to:	
Experience a coughing spell (Never [0] to Always [10])	Cavazos-Rehg et al., 2016
Vomit/throw up (Never [0] to Always [10])	Cavazos-Rehg et al., 2016
To what extent does [marijuana/butane hash oil] cause you to:	
Feel heaviness in your limbs (Not at all [0] to Extremely [10])	Cavazos-Rehg et al., 2016
Feel as if things are tight on your skin or in your body (Not at all [0] to Extremely [10])	Quinn et al., 2017
Feel dizzy (Not at all [0] to Extremely [10])	Hunault et al., 2014
Feel like your heart is pounding faster than usual (Not at all [0] to Extremely [10])	Cavazos-Rehg et al., 2016
Feel pain in your lungs (Not at all [0] to Extremely [10])	Cavazos-Rehg et al., 2016
Have difficulty breathing (Not at all [0] to Extremely [10])	Cavazos-Rehg et al., 2016
Lose control of your body (Not at all [0] to Extremely [10])	Cavazos-Rehg et al., 2016
Reduced Consciousness Scale	
How often [marijuana/butane hash oil] cause you to:	
Black out (Never [0] to Always [10])	Cavazos-Rehg et al., 2016
Lose consciousness (Never [0] to Always [10])	Cavazos-Rehg et al., 2016
Pass out (Never [0] to Always [10])	Cavazos-Rehg et al., 2016
To what extent does [marijuana/butane hash oil] cause you to feel:	
Reduced level of consciousness (Not at all [0] to Extremely [10])	Quinn et al., 2017

Table 2. Comparison of Infrequent and Frequent Hash Oil Users on Demographics and Cannabis Use

Correlate	Full sample (n = 574) M/% (SD)	Infrequent hash oil users (n = 312) M/% (SD)	Frequent hash oil users (n = 262) M/% (SD)	t/χ^2	p
Demographics					
Age	32.21 (12.62)	32.29 (12.78)	32.12 (12.45)	1.06	0.65
Sex (% male)	55.40%	50.00%	61.83%	χ^2 = **8.39**	**0.02**
Marijuana Use					
Frequency[a]	10.07 (2.69)	9.98 (2.77)	10.18 (2.59)	-0.88	0.38
Duration of use at current frequency[b]	8.31 (2.69)	8.38 (2.73)	8.23 (2.64)	0.63	0.53
Hash Oil Use					
Frequency[a]	5.63 (3.78)	2.65 (1.40)	9.18 (2.42)	---	---
Duration of use at current frequency[b]	5.73 (2.63)	5.62 (2.79)	5.87 (2.43)	-1.10	0.27
Medical Cannabis Card (% with card)	33.10%	25.64%	41.98%	χ^2 = **17.18**	**<.001**

Note: Infrequent hash oil users (individuals who used hash oil no more than once per month) and frequent hash oil users (individuals who use more than once a month) were designated through a median split. Dashes (--) indicate that we did not conduct a test of group differences in frequency of hash oil use, because groups were selected based on frequency of hash oil use.

a. Frequency of use was scored as follows: 0 = never used, 1 = less than once a year, 2 = once a year, 3 = once every 3 to 6 months (2 to 4 times per year), 4 = once every 2 months (6 times per year), 5 = once a month (12 times per year), 6 = 2 to 3 times per month, 7 = once a week, 8 = twice a week, 9 = 3 to 4 times a week, 10 = 5 to 6 times a week, 11 = once a day, 12 = more than once a day.

b. Length of use at current frequency was scored as follows: 1 = less than 1 month, 2 = 1 to 3 months, 3 = 3 to 6 months, 4 = 6 to 9 months, 5 = 9 to 12 months, 6 = 1 to 2 years, 7 = 2 to 3 years, 8 = 3 to 5 years, 9 = 5 to 10 years, 10 = 10 to 15 years, 11 = 15 to 20 years, 12 = more than 20 years.

Table 3. Within-Person Comparisons of the Subjective Effects of Marijuana and Hash Oil

	Marijuana		Hash Oil				
Subjective Effect	**M (SD)**	**Range**	**M (SD)**	**Range**	**Cohen's *d***	***Paired t*-test**	***p*-value**
Positive Effects Total	5.55 (1.70)	0.31 – 10.00	4.53 (2.13)	0.00 – 10.00	0.68	**14.67**	< **.001**
Positive Affect – Low Arousal	7.59 (1.71)	0.00 – 10.00	6.51 (2.41)	0.00 – 10.00	0.52	**11.03**	<**.001**
Positive Affect – High Arousal	4.02 (2.00)	0.00 – 10.00	3.52 (2.35)	0.00 – 10.00	0.30	**9.64**	<**.001**
Cognitive Enhancement	5.52 (2.27)	0.00 – 10.00	4.16 (2.61)	0.00 – 10.00	0.72	**16.49**	<**.001**
Negative Effects Total	1.38 (1.09)	0.00 – 8.66	1.41 (1.30)	0.00 – 8.13	-0.01	1.63	0.10
Negative Affect – Low Arousal	0.84 (1.42)	0.00 – 9.50	0.54 (1.21)	0.00 – 9.00	0.36	**9.38**	<**.001**
Negative Affect – High Arousal	1.74 (1.74)	0.00 – 10.00	1.65 (2.06)	0.00 – 9.20	0.07	**5.25**	<**.001**
Psychotic-like Experiences	1.21 (1.23)	0.00 – 10.00	1.06 (1.34)	0.00 – 8.00	0.19	**7.33**	< **.001**
Cognitive Impairment	2.41 (1.67)	0.00 – 10.00	2.34 (1.98)	0.00 – 10.00	0.06	**4.80**	< **.001**
Physiological Effects	1.22 (1.12)	0.00 – 8.88	1.66 (1.52)	0.00 – 9.63	-0.38	**-8.22**	< **.001**
Reduced Consciousness	0.52 (0.92)	0.00 – 9.25	0.65 (1.17)	0.00 – 8.50	-0.16	**-2.55**	**.01**

Note: *Paired t*-tests were based on log-transformed subjective effects but means and Cohen's *d* effect sizes were not log-transformed. Due to missing data, Ns for statistical tests ranged from 545 to 566 depending on subjective effect scale. Scales ranged from 0 to 10 (not at all [0] to extremely [10] or never [0] to always [10]).

Table 4. Test of Whether Marijuana and Hash Oil Ratings Differ as a Function of Frequency of Hash Oil Use

	Marijuana Subjective Effects								Hash Oil Subjective Effects							
	Infrequent hash oil users (n = 312)	Frequent hash oil users (n = 262)	Regressing marijuana subjective effects on frequency of hash oil use			Regressing marijuana subjective effects on frequency of hash oil use, controlling for sex, medical cannabis use, and frequency of marijuana use			Infrequent hash oil users (n = 312)	Frequent hash oil users (n = 262)	Regressing hash oil subjective effects on frequency of hash oil use			Regressing hash oil subjective effects on frequency of hash oil use, controlling for sex, medical cannabis use, and frequency of marijuana use		
Subjective Effect	*M(SD)*	*M(SD)*	β	*t*-test	*p*	β	*t*-test	*p*	*M(SD)*	*M(SD)*	β	*t*-test	*p*	β	*t*-test	*P*
Positive Effects Total	5.61 (1.69)	5.49 (1.72)	-0.00	-0.08	0.94	-0.01	0.13	0.89	4.14 (2.18)	5.00 (1.96)	**0.28**	**6.86**	**<.001**	**0.29**	**7.03**	**<.001**
Positive Affect – Low Arousal	7.62 (1.74)	7.54 (1.68)	0.01	0.32	0.75	0.02	0.47	0.64	6.06 (2.61)	7.06 (2.02)	**0.28**	**6.81**	**<.001**	**0.29**	**7.04**	**<.001**
Positive Affect – High Arousal	4.03 (1.94)	4.02 (2.07)	-0.00	-0.06	0.95	0.00	0.04	0.97	3.27 (2.29)	3.82 (2.38)	**0.15**	**3.63**	**<.001**	**0.17**	**4.01**	**<.001**
Cognitive Enhancement	5.61 (2.25)	5.42 (2.28)	0.00	0.07	0.95	0.01	0.14	0.89	3.69 (2.60)	4.71 (2.51)	**0.28**	**6.81**	**<.001**	**0.27**	**6.56**	**<.001**
Negative Effects Total	1.42 (1.04)	1.33 (1.15)	**-0.12**	**-2.81**	**0.01**	**-0.09**	**-2.18**	**0.03**	1.56 (1.32)	1.22 (1.24)	**-0.16**	**-3.83**	**<.001**	**-0.16**	**-3.69**	**<.001**
Negative Affect – Low Arousal	0.83 (1.39)	0.86 (1.47)	-0.05	-1.18	0.24	-0.05	-1.21	0.23	0.48 (1.04)	0.60 (1.38)	0.02	0.41	0.68	0.01	0.25	0.80
Negative Affect – High Arousal	1.90 (1.77)	1.57 (1.70)	**-0.12**	**-2.96**	**<.01**	**-0.11**	**-2.65**	**0.01**	1.95 (2.21)	1.30 (1.81)	**-0.17**	**-4.01**	**<.001**	**-0.16**	**-3.86**	**<.001**
Psychotic-like Experiences	1.25 (1.26)	1.16 (1.19)	-0.07	-1.71	0.09	-0.07	-1.54	0.12	1.16 (1.39)	0.94 (1.27)	**-0.10**	**-2.43**	**0.02**	**-0.10**	**-2.30**	**0.02**
Cognitive Impairment	2.49 (1.68)	2.33 (1.67)	**-0.09**	**-2.11**	**0.04**	-0.08	-1.81	0.07	2.61 (2.11)	2.03 (1.77)	**-0.13**	**-3.15**	**<.01**	**-0.12**	**-2.91**	**<.01**
Physiological Effects	1.22 (1.04)	1.23 (1.21)	-0.07	-1.61	0.11	-0.05	-1.23	0.22	1.82 (1.59)	1.46 (1.40)	**-0.13**	**-3.15**	**<.01**	**-0.13**	**-3.03**	**<.01**
Reduced Consciousness	0.48 (0.73)	0.58 (1.11)	-0.02	-0.54	0.59	-0.02	-0.52	0.60	0.67 (1.10)	0.64 (1.25)	-0.07	-1.63	0.10	-0.08	-1.80	0.07

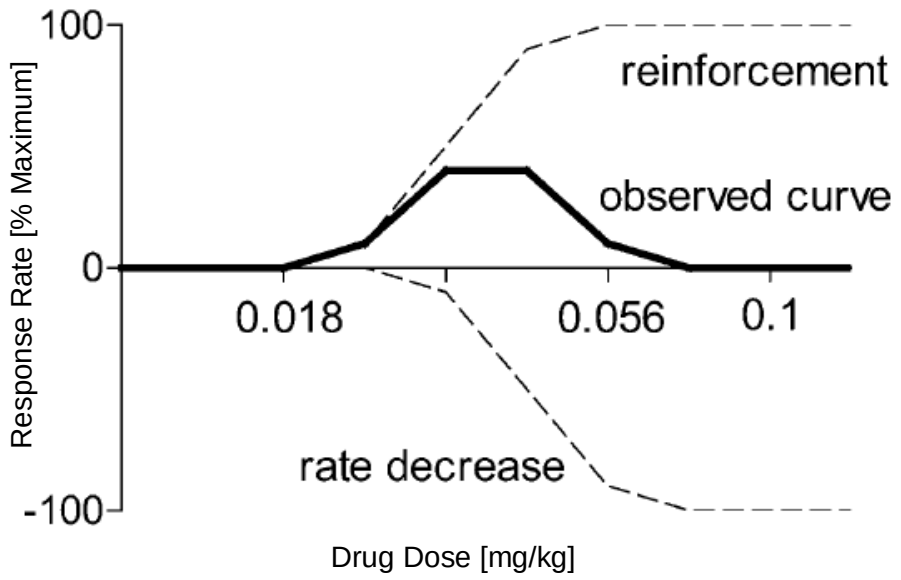
Note: To ascertain if ratings of marijuana and hash oil differed as a function of hash oil use, each subjective effect (e.g., positive effects for marijuana, positive effects for hash oil) was regressed on frequency of hash oil use. To aid interpretation of statistical tests, means for infrequent vs. frequent hash oil users (based on a median split) are reported. Statistical tests were based on log-transformed subjective effects but means were not log-transformed. Beta coefficients are standardized. Due to missing data, Ns for statistical tests ranged from 552 to 570 depending on subjective effect scale. Scales ranged from 0 to 10 (not at all [0] to extremely [10] or never [0] to always [10]).

Table 5. Test of Whether Difference Ratings for Marijuana and Hash Oil Differ as a Function of Frequency of Hash Oil Use

	Infrequent hash oil users (n = 312)						Frequent hash oil users (n = 262)						Regressing difference scores on frequency of hash oil use			Regressing difference scores on frequency of hash oil use, controlling for sex, medical cannabis use, and frequency of marijuana use		
Subjective Effect	MJ M (SD)	Hash oil M (SD)	Differ-ence	*Cohen's d*	*Paired t*-test	*p*	MJ M (SD)	Hash oil M (SD)	Differ-ence	*Cohen's d*	*Paired t*-test	*p*	β	*t*-test	*p*	β	*t*-test	*p*
Positive Effects Total	5.61 (1.69)	4.14 (2.18)	1.47	0.87	**13.41**	**<.001**	5.49 (1.72)	5.00 (1.96)	0.49	0.47	**7.85**	**<.001**	**-0.37**	**9.53**	**<.001**	**-0.39**	**-9.72**	**<.001**
Positive – Low Arousal	7.62 (1.74)	6.06 (2.61)	1.56	0.67	**10.01**	**<.001**	7.54 (1.68)	7.06 (2.02)	0.48	0.34	**5.72**	**<.001**	**-0.30**	**-7.50**	**<.001**	**-0.31**	**-7.66**	**<.001**
Positive – High Arousal	4.03 (1.94)	3.27 (2.29)	0.76	0.41	**8.97**	**<.001**	4.02 (2.07)	3.82 (2.38)	0.20	0.14	**4.17**	**<.001**	**-0.17**	**-3.99**	**<.001**	**-0.19**	**-4.39**	**<.001**
Cognitive Enhancement	5.61 (2.25)	3.69 (2.60)	1.92	0.94	**15.38**	**<.001**	5.42 (2.28)	4.71 (2.51)	0.71	0.50	**8.10**	**<.001**	**-0.38**	**-9.64**	**<.001**	**-0.38**	**-9.55**	**<.001**
Negative Effects Total	1.42 (1.04)	1.57 (1.33)	-0.15	-0.15	-1.02	0.31	1.32 (1.15)	1.22 (1.24)	0.11	0.26	**4.64**	**<.001**	**0.15**	**3.55**	**<.001**	**0.16**	**3.73**	**<.001**
Negative – Low Arousal	0.83 (1.39)	0.48 (1.04)	0.35	0.34	**7.14**	**<.001**	0.86 (1.47)	0.60 (1.38)	0.26	0.33	**6.11**	**<.001**	-0.08	-1.92	0.06	-0.07	-1.63	0.10
Negative – High Arousal	1.90 (1.77)	1.95 (2.21)	-0.05	-0.03	**2.15**	**0.03**	1.57 (1.70)	1.30 (1.81)	0.27	0.25	**6.02**	**<.001**	**0.12**	**2.87**	**<.001**	**0.13**	**2.99**	**<.01**
Psychotic-like Experiences	1.25 (1.26)	1.16 (1.39)	0.09	0.09	**3.74**	**< .001**	1.16 (1.19)	0.94 (1.27)	0.22	0.36	**7.50**	**< .001**	0.06	1.46	0.14	0.06	1.36	0.17
Cognitive Impairment	2.49 (1.68)	2.61 (2.11)	-0.12	-0.07	1.42	0.16	2.33 (1.67)	2.03 (1.77)	0.30	0.30	**6.08**	**< .001**	**0.14**	**3.45**	**<.001**	**0.15**	**3.36**	**<.001**
Physiological Effects	1.22 (1.04)	1.82 (1.59)	-0.60	-0.46	**-7.34**	**< .001**	1.23 (1.21)	1.46 (1.40)	-0.23	-0.27	**-3.96**	**< .001**	**0.18**	**4.21**	**<.001**	**0.20**	**4.66**	**<.001**
Reduced Consciousness	0.48 (0.73)	0.67 (1.10)	-0.19	-0.20	**-2.80**	**0.01**	0.58 (1.11)	0.64 (1.25)	-0.06	-0.08	-0.46	0.65	0.08	1.78	0.08	0.09	1.99	0.05

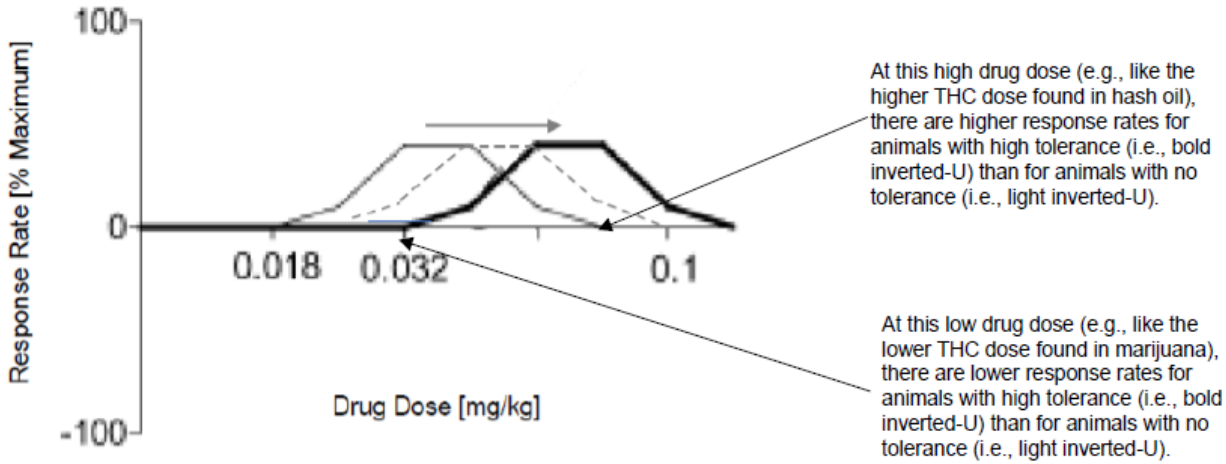
Note: To ascertain if the relative differences in ratings between marijuana and hash oil differed as a function of frequency of hash oil use, difference scores for each subjective effect domain (e.g., marijuana positive effects rating minus hash oil positive effects rating) was regressed on frequency of hash oil use. For example, this table shows that although marijuana was rated as producing greater positive effects than hash oil in both infrequent and frequent hash oil users, the extent to which marijuana was rated as producing greater positive effects than hash oil was attenuated for frequent hash oil users (5.08 - 4.71= 0.37) compared with infrequent hash oil users 5.19 - 3.92 = 1.27). To aid interpretation of statistical tests, means for infrequent vs. frequent hash oil users (based on median split) are reported and *paired t*-tests were used to test within person difference ratings (marijuana ratings minus hash oil ratings) between marijuana and hash oil within each group. *Paired t*-tests were based on log-transformed subjective effects and regressions were based on log-transformed difference scores but means and Cohen's *d* effect sizes were based on non-log-transformed variables. Beta coefficients are reported in standardized form. Due to missing data, Ns ranged from 546 to 566 for regression analyses depending on subjective effect scale. Ns ranged from 297 to 307 for paired t-tests of infrequent hash oil users and Ns ranged from 249 to 259 for paired t-tests of frequent hash oil users. Scales ranged from 0 to 10 (not at all [0] to extremely [10] or never [0] to always [10]).
MJ = Marijuana.

Figure 1. Inverted U-Shaped Reward-Aversion Dose-Effect Curve



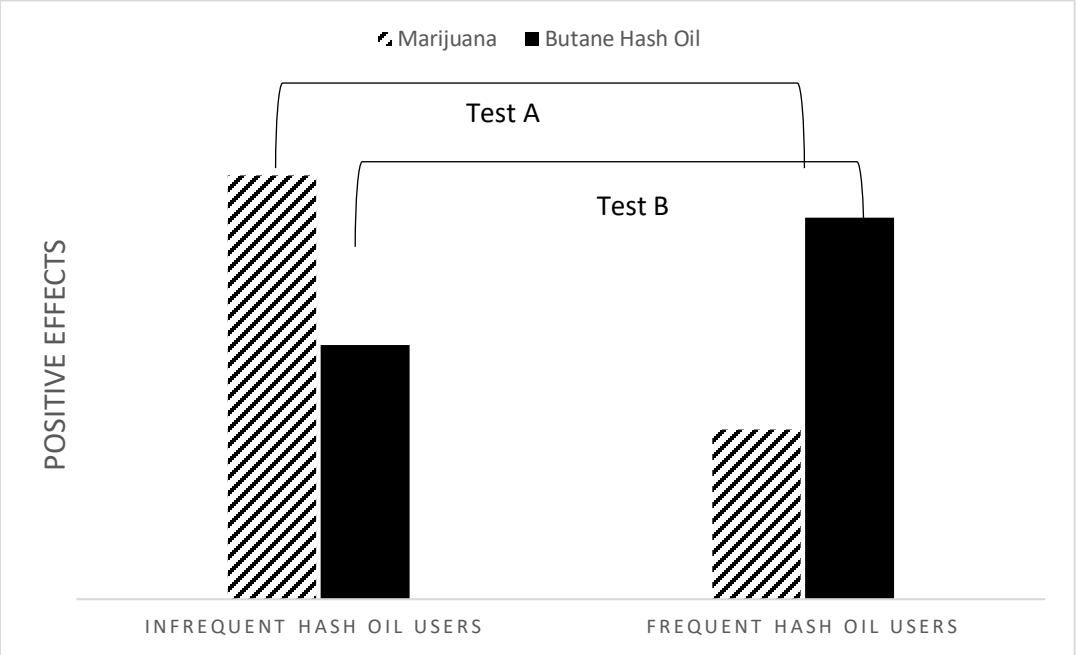
Note: This figure is taken from Zernig et al., 2004 and illustrates the inverted U-shaped reward-aversion dose-effect curve in animal models whereby medium drug doses are more desirable than low or high drug doses. Zernig et al. (2004) suggests that this inverted U-shaped curve occurs because negative drug effects (labeled "rate decrease" in the figure) increase with increasing dose and counteract the positive effects (labeled "reinforcement" in the figure). This observed inverted U-shaped dose-effect curve has also been found in humans as well (Curran et al., 2016; Hunault et al., 2014; Sanudo-Pena et al., 1997).

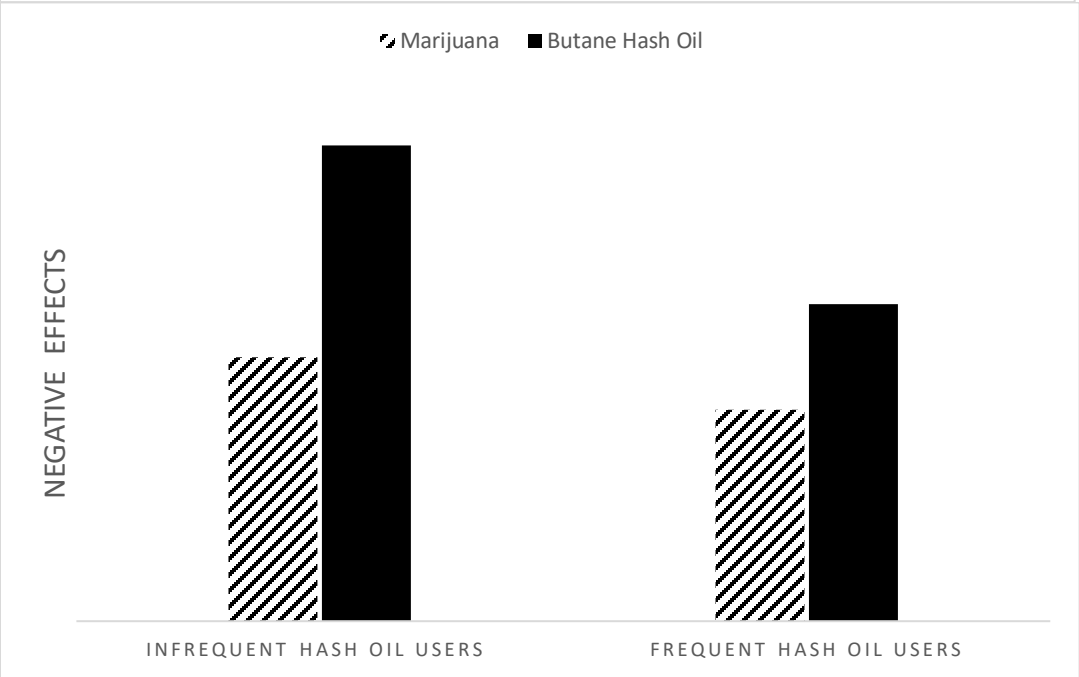
Figure 2. Tolerance-Related Lateral Shift of Inverted U-Shaped Curve



Note: The above figure is adapted from Zernig and colleagues (2004). This figure illustrates the inverted U-shaped curve shifting laterally to the right as a function of tolerance. That is, the inverted U-shaped curve for the control condition (no tolerance), which is shown in light gray, shifts to the right as tolerance develops (shown in black). Thus, at low doses (e.g., .032), animals with increased tolerance (black curve) have lower response rates than animals with no tolerance (light gray curve). At high drug doses, animals with increased tolerance (black curve) have higher response rates than animals with no tolerance (light gray curve). This is because animals with no tolerance experience negative effects that counteract the positive effects at high doses.

Figure 3. Hypothesized Association of the Subjective Effects of Marijuana Versus Hash Oil Among More and Less Frequent Hash Oil Users





Note: Test A shows the hypothesized association of positive and negative subjective effects of marijuana for infrequent vs. frequent hash oil users. Test B shows the hypothesized association of positive and negative effects of hash oil for infrequent vs. frequent hash oil users.

Figure 4. Images of Marijuana (Panel A) and Butane Hash Oil (Panel B)

Panel A: Marijuana. Below is **marijuana**, as it will be referred to in this survey. It is also known as herb, grass, bud, pot, weed, and flower.

Panel B. Butane Hash Oil. Below is **butane hash oil (BHO)**, as it will be referred to in this survey. It is also known as concentrate, wax, dab, honey oil, BHO, crumble, shatter, glass, honeycomb, earwax, or budder/budda. **Please note that these pictures are to be used as references. Some hash oil may look different from the ones picture**

APPENDIX I

VALIDITY QUESTIONS

Validity Questions

Question	Answer
Does a circle have three sides?	*'No'*
Does the word 'cat' have ten letters?	*'No'*
Is the earth round?	*'Yes'*
Is the sun hot?	*'Yes'*
What is two plus two?	*'Four'*
Please select 'Moderately Agree'	*'Moderately Agree'*
Select '5'	*'5'*
Select '6'	*'6'*
Select '6'	*'6'*
Select '10'	*'10'*
Select '10'	*'10'*

Note: Participants answered the above questions, which were placed throughout the survey, to check validity of responses. To be included in the final analyses, participants had to have correctly answered at least 75% of the questions.

APPENDIX II

INSTITUTIONAL REVIEW BOARD (IRB) STUDY APPROVAL

ASU Knowledge Enterprise Development

EXEMPTION GRANTED

Madeline Meier
Psychology
-
Madeline.Meier@asu.edu

Dear Madeline Meier:

On 9/2/2017 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Online Survey of Cannabis Concentrates Use
Investigator:	Madeline Meier
IRB ID:	STUDY00006641
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Concentrates Survey_Supplemental Form_8.28.2017.docx, Category: IRB Protocol; • Concentrate Survey_ Bluelight Message Board Post_8.28.2017.pdf, Category: Recruitment Materials; • Concentrates Survey_Informed Consent_8.28.2017.pdf, Category: Consent Form; • Concentrates_Survey_ Questionnaire Battery_8.31.2017.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 9/2/2017.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).