Reactivity to Daily Self-Monitoring of Cannabis Use in Biological Females

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ABSTRACT

Assessment reactivity involves changes to behaviours from self-monitoring those behaviours (Nelson & Hayes, 1981). In the substance use field, reactivity has been identified both as a potential confound in daily diary research (Cohn et al., 2015) and as a possible intervention tool in clinical practice (Cohn et al., 2018). Reactivity to daily self-monitoring of alcohol and tobacco use has been inconsistent in prior research. Reactivity to daily self-monitoring of cannabis use quantity has received far less study. This study involved secondary analyses of data from $N = 88$ females who self-monitored their cannabis use for 32 days. We examined objective reactivity of cannabis use to daily self-monitoring by assessing changes in daily cannabis use over 32 days. We also explored participants' perceptions of the impact daily self-monitoring had on their cannabis use at study completion (i.e., subjective reactivity). In hurdle models testing objective reactivity, neither probability of cannabis use, nor quantity of cannabis use, changed significantly over the study period. Many respondents (45%) reported no subjective reactivity, though a slight majority (55%) reported some subjective reactivity. Subjective reactivity did not moderate objective reactivity over time; however, higher subjective reactivity was significantly associated with increased variability (interquartile range [IQR]) in cannabis use across the self-monitoring period. Overall, reactivity appears unlikely to confound research utilizing daily diary cannabis measures, and daily self-monitoring of cannabis use may be unlikely to serve as a useful stand-alone intervention for reducing cannabis use in non-treatment-seeking individuals. Potential clinical implications of the novel finding of a link between subjective reactivity and objective cannabis use variability are discussed.

Key words: = cannabis; cannabis use quantity; assessment reactivity; longitudinal; daily diary; hurdle models

Assessment reactivity refers to behavior change that occurs due to self-monitoring (Nelson & Hayes, 1981). In the addictions field, reactivity to daily self-monitoring has been identified as an intervention tool in clinical practice (Cohn et al., 2018), that may also introduce measurement bias in daily diary research (Cohn et al., 2015). Reactivity to daily self-monitoring of substance use is thought to occur due to increased awareness of use (Moos, 2008).

Objective reactivity to daily self-monitoring (i.e., systematic mean changes over time) has been demonstrated for alcohol and tobacco use. In an 8-week intervention study with heavy drinkers, participants in the control condition, who had self-monitored their alcohol use up to six times/day, significantly decreased their alcohol consumption over time (Collins et al., 1998). In another study of treatment-seeking smokers randomized to self-monitor cigarette craving either once or six times/day for four-weeks (McCarthy et al., 2015), higher frequency self-monitoring was associated with lower craving over time. However, other studies with both clinical and non-clinical samples have failed to identify alcohol reactivity during shorter self-monitoring intervals of two to four weeks (e.g., Hufford et al., 2002; Simpson et al., 2005).

Buu et al. (2020) investigated reactivity to cannabis use daily self-monitoring. Three-hundred-and-seven emerging adults self-monitored their cannabis use daily or weekly for 90 days. While no evidence of reactivity to daily self-monitoring on probability of cannabis use or

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cannabis use frequency (number of use occasions/day) was found in either self-monitoring group, they did not examine quantity (i.e., how much or what dose of cannabis was used; Day & Robles, 1989; Zeisser et al., 2012) – a cannabis outcome that warrants further exploration (Asbridge et al., 2014). The focus on cannabis quantity in the present study represents a necessary addition to the reactivity literature given that quantity of cannabis consumed has been shown to have effects that are independent of cannabis frequency in predicting cannabis-related problems (Walden & Earleywine, 2008). Additionally, some have emphasized that definitions of risky or harmful substance use should not be predicated on frequency of use alone (e.g., Rehm, 1998).

Subjective reactivity (i.e., participants' self-rated perceptions of reactivity) is rarely investigated. In a study by Hufford et al. (2002), a sample of heavy drinking undergraduates perceived mild reactivity effects to daily self-monitoring of their drinking behavior (M=2.1 on a 0-10 scale, with "0" indicating "not at all" and "10" indicating "a great deal"). To our knowledge, subjective reactivity has not been examined for cannabis use, and researchers have not yet examined associations between subjective and objective reactivity. Such an examination would clarify whether cannabis users are aware of the reactivity effects that are occurring, or whether such effects may be occurring without their conscious awareness.

The objectives of the present study were to investigate: (1) objective cannabis reactivity by replicating Buu et al.'s (2020) analysis of cannabis use probability and extending to quantity of cannabis used; (2) participants' perceptions of the impact of daily self-monitoring on their cannabis use to assess if subjective reactivity exists; (3) if subjective reactivity moderated the rate of change over time (i.e., do people high in subjective reactivity display larger decreases in cannabis use over time on the daily self-monitoring?); and (4) whether people high in subjective reactivity have greater day-to-day variability in cannabis use. Consistent with findings demonstrated by the limited existing research on daily diary cannabis reactivity (Buu et al., 2020), we hypothesized that cannabis use (probability and quantity) would decrease significantly over the 32 days of daily self-monitoring. Similarly, based on limited existing findings with alcohol (Buu et al., 2020; Hufford et al., 2002), we predicted that participants would perceive overall mild reactivity effects of daily self-monitoring on their cannabis use. Regarding the hypothesized effect of subjective reactivity on daily self-reported rate of change, we expected that individuals reporting the greatest subjective reactivity would also be those with the greatest objective change, reflecting participant awareness of assessment reactivity effects (Moos, 2008). Finally, participants high in subjective reactivity were hypothesized to also demonstrate higher variability in use because we expected that when people subjectively report having experienced higher levels of assessment reactivity, what they may have been noticing was day-to-day variations in use.

METHODS

Participants

Eighty-eight female[1] cannabis users (M_{age}=28.86 years, SD=6.11, Range=19-45) were originally recruited via advertisement for a study on cannabis use across the menstrual cycle (Joyce, 2019; Joyce et al., 2021). Eligibility criteria included: aged 19-45 years, access to a smart phone with a data/texting plan (daily diary surveys were sent to participants via text message and accessed through the internet), using cannabis >4 times/past month, and not attempting to abstain from cannabis or receiving cannabis treatment.[2] Participants could not have a current pain disorder diagnosis or a medicinal cannabis prescription as these might minimize reactivity to daily self-monitoring. Most participants were identified as daily users and having hazardous use/a possible cannabis use

[1]Participants for the original study (Joyce, 2019; Joyce et al. 2021) were required to have a menstrual cycle, and thus were biologically female by birth. Information was not originally obtained on gender. As such, we do not use the term "woman/women" to describe participants, as participants may not have identified as women.

[2]Additional inclusion criteria for the [deidentified study citation 1] study examining depressed mood and coping motive effects on cannabis use quantity across the menstrual cycle included: (1) no menstrual cycle interference (e.g., past 6 month/current pregnancy, past 3-month contraceptive use), (2) a menstrual cycle between 25 and 32 days long, and (3) no imminent plans of conceiving. While these additional inclusion criteria were not relevant for the current study on reactivity to daily self-monitoring of cannabis use, they are mentioned here since they may affect generalizability.

disorder (see Table 1). For the original study (Joyce, 2019; Joyce et al., 2021), 232 females were screened and 112 were deemed eligible. Of those deemed eligible, 24 were scheduled but did not attend the first session, resulting in our final sample of 88 participants. The 88 participants in our study included the 69 participants analyzed in the original study, with an additional 19 participants included in our current analysis. Data for all 88 participants was collected in the original study; however, the original analyses excluded participants (N= 19) who completed less than 70% of their daily diaries. We retained all 88 participants for our current study. While a 70% completion rates is typically required to be sufficient for daily diary data (Gordon, 2002), we utilized statistical models for the current study that were well able to accommodate missing data.

Procedure

This study consisted of four sessions. Session one included telephone eligibility screening. Once deemed eligible, participants were scheduled for session 2 which occurred during specific menstrual cycle days (Joyce, 2019; Joyce et al., 2021); this ensured reactivity effects would not be confounded by menstrual cycle phase. During session 2, informed consent was provided, a demographics questionnaire was completed, and participants were taught how to use their smartphone to answer surveys. The self-monitoring period (session 3) started the next day. Participants received daily text messages with an online survey link for 32 days. Every day at 10:30 am, participants were asked the total quantity of cannabis used the prior day. Participants completed two daily questions on their cannabis use quantity: one at 10:30am and another at 2pm (Joyce, 2019). Further, a daily reminder to complete the 2pm survey was sent at 6:30pm. The 2pm survey only included information on the participants most recent use of cannabis that day. The 10:30am assessment captured the total quantity of cannabis used the previous day, so we deemed the 10:30am survey to be the most appropriate for this study given our novel focus on quantity. Following the self-monitoring period, participants completed session 4 where they answered a subjective reactivity questionnaire, were debriefed, and obtained compensation (up to $97.65/CND).

Measures

Measures for the current study were chosen from among a broader set used in the original study (Joyce, 2019; Joyce et al., 2021) to focus solely on cannabis use reactivity effects over the self-monitoring period.

Demographics. A demographics questionnaire, including items assessing participant characteristics such as age, ethnicity, and education, was administered at baseline for sample description purposes.

Cannabis Timeline Followback (CTLFB; Robinson et al., 2014). The CTLFB, a calendar-based retrospective measure, was administered at baseline to determine participants' recent cannabis use habits (e.g., cannabis-using days during the past 30 days). The measure assessed various cannabis use behaviours such as type and amount of cannabis used (Sobell & Sobell, 1992). Participants were shown a calendar and asked to provide information about salient occasions (e.g., birthdays or holidays) during the past 30 days to act as memory anchors for increasing the accuracy of their cannabis use self-reports. The CTLFB has been found to have high test-retest reliability over a 30-day period (r = .79 to .96; Robinson et al., 2014) as well as high concurrent validity with biological measures over a 30-day period (percentage agreement = 87.4 to 91.9; Hjorthøj et al., 2012).

The Cannabis Use Disorder Identification Test - Revised (CUDIT-R; Adamson & Sellman, 2003). The CUDIT-R is an eight-item measure used to assess cannabis use disorder symptoms amongst at-risk populations. It was administered at baseline to identify hazardous/disordered vs. non-problematic cannabis users. The CUDIT-R has demonstrated good internal consistency (α = .84) and test-retest reliability (between six and 12 months; r = .85 - .87, respectively; Adamson & Sellman, 2003). In our sample, the CUDIT-R demonstrated an internal consistency of α = .66. While lower than in the validation study (Adamson & Sellman, 2003), our alpha was greater than .60 – a cut-off deemed to be acceptable for the internal consistency of short scales of less than 10 items (Loewenthal, 2004). A score of 13 or more was the cut-off point used to establish problematic cannabis use on the CUDIT-R (Adamson et al., 2010).

Table 1. *Demographic Information for Full Sample (N = 88)*

Demographic Variable	Valid *N*	*M* (*SD*)/%	Range
Ethnicity[a]	87		
Caucasian		87.36%	
First Nations		11.49%	
Black		6.90%	
South Asian		4.60%	
Arabic/West Asian		4.60%	
Latin American		2.30%	
East or Southeast Asian		2.30%	
Other		3.45%	
Education Level	87		
College/University Graduate or More[b]		68.97%	
Some College/University or Less[c]		31.03%	
Cannabis Use Risk[d]	87		
Hazardous Use or More[e]		58.60%	
Non-problematic Cannabis Use		41.40%	
Cannabis Using Days (30-Days Pre-Study)[f]	88	24.53 (8.55)	2 – 30
Cannabis Using Days (Daily Diary Study)[g]	88	21.05 (9.38)	3 – 32
Daily Cannabis Use (30-Days Pre-Study)[f]		57.95%	
Age (in years)	87	28.86 (6.11)	19 – 45
Current Mood-Related Disorder Diagnoses[h]	87		
Pre-Menstrual Dysphoric Disorder		27.5%	
Persistent Depressive Disorder		17.6%	
Cyclothymic Disorder		8.8%	
Hypomanic Episode		1.5%	
Manic Episode		0.0%	

[a]Ethnic categories are not mutually exclusive as people could identify with more than one ethnic category (e.g., biracial individuals).
[b]Includes: College/University Graduate, Some Post-Graduate, and Post-Graduate Degree
[c]Includes: Some College/University, High School Graduate, and Some High School
[d]Determined by Cannabis Use Disorder Identification Test-Revised (Adamson & Sellman, 2003)
[e]Includes: Hazardous Cannabis Use and Cannabis Use Disorder. A cutoff score of 13 and above was used to identify hazardous cannabis users (Adamson et al., 2010).
[f]Determined by Cannabis Timeline Followback (Robinson et al., 2014)
[g]Determined by ecological momentary assessment
[h]Determined by the Structured Clinical Interview for DSM-5 Disorders – Research Version (First et al., 2015). The SCID-5-RV is the gold standard for mood disorder diagnoses (First et al., 2015) with good test-retest reliability across one week (r = .76) and very good-to-excellent inter-rater reliability (κ = 0.62-0.82) for depressive disorders (Tolin et al., 2018).

Table 2. *Missing Data for Full Sample (N = 88) across All 32 Days*

Day	Missing (%)
1	56.8
2	44.3
3	59.1
4	54.5
5	54.5
6	58.0
7	61.4
8	61.4
9	65.9
10	60.2
11	63.6
12	68.2
13	68.2
14	64.8
15	70.5
16	61.4
17	60.2
18	67.0
19	69.3
20	64.8
21	70.5
22	72.7
23	68.2
24	65.9
25	65.9
26	71.6
27	71.6
28	68.2
29	70.5
30	72.7
31	69.3
32	73.9

Daily Self-Monitoring. At the 10:30am daily assessment, participants were asked if they had used cannabis the previous day (yes/no). When participants reported previous day cannabis use, they were prompted to indicate the quantity of cannabis used via the number of standard joint equivalents. They were told a standard joint referred to .5 grams, five bong/pipe hits, and/or 10 puffs (Zeisser et al., 2012). Reported instances of cannabis edibles and concentrates (5 and 5 out of 2816 days, respectively) were eliminated from cannabis use quantity calculations due to a lack of research equating cannabis quantity across different types of cannabis (e.g., flower, edible, or concentrates). Participants had until 11:59pm each day to record their responses, and failure to respond by the deadline resulted in missing data for that day.

Subjective Perception of Reactivity. At session 4, participants were asked to rate, on a 10-point scale, "To what extent did the monitoring impact your cannabis use behaviors" (1="*not at all*", 5="*moderately*", 10="*a great deal*") similar to previous alcohol research (Hufford et al., 2002).

Data Analysis

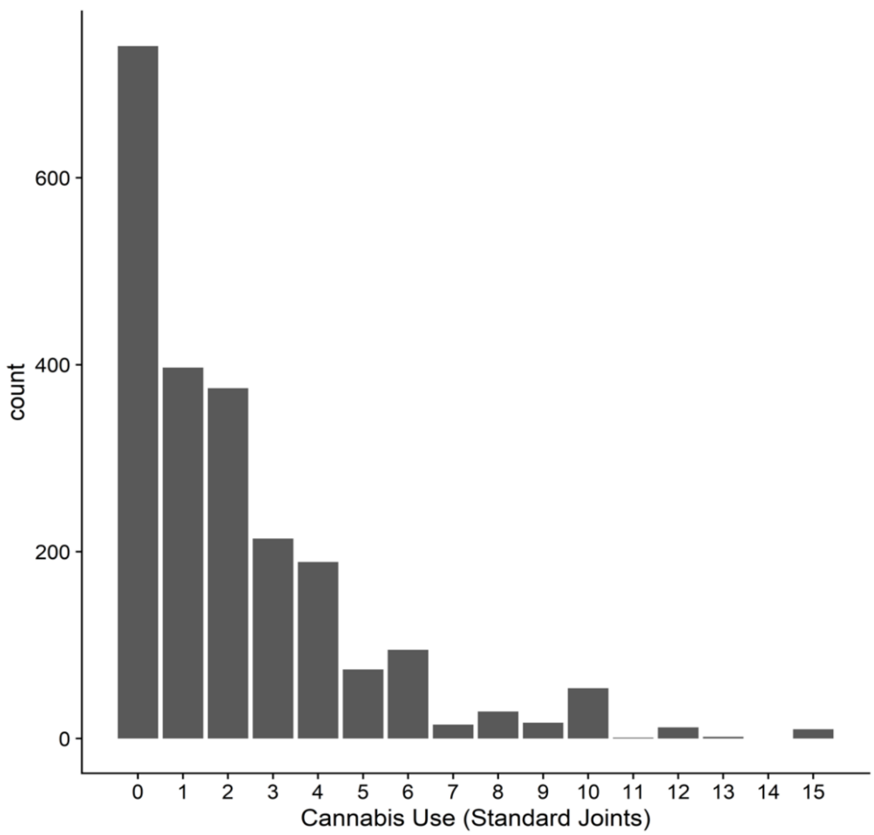
The study design was repeated measures nested within participants. Hurdle models were chosen to examine change in cannabis use both between- and within-participants over 32-days. Day of study was entered as a linear predictor of cannabis use. Nested model comparison was used to compare different distributional assumptions. Models were run in R version 3.6 (R Development Core Team) using the 'glmmTMB' package (Brooks et al., 2017) where models are fit using maximum likelihood estimation (MLE).[3] MLE is one way to help reduce bias of parameter estimates in the presence of missing data (65.8% of all our possible observations were missing). This approach assumes we can predict missingness from variables in the model. Missing data was found to be higher for later days of data collection (see Table 2), which supports the missing at random condition.

RESULTS

Nested Model Comparison

Cannabis use was positively skewed with zero-inflation (Figure 1). Model fit was tested with zero-inflated negative binomial, zero-inflated Poisson, and Hurdle models.[4] Negative binomial models and the fixed slopes Poisson models failed to converge. All models had random intercepts. Three models were compared: Random slopes zero-inflated Poisson (AIC = 6248.0), fixed slopes hurdle (AIC = 6201.1), and random slopes hurdle (AIC = 6180.3; best-fitting model). The hurdle model allowed us to examine zeros (i.e., using versus not using cannabis) and numerical differences in cannabis quantity separately in a single model.

Figure 1. *Histogram of Cannabis Scores*



Note. Scores are indicated by "standard joint equivalents", reported by participants (N = 88) for the full period of data collection. There were 2226 total usable observations (79% of a possible 2816) across participants, including zero values.

Cannabis Use Over 32-Days

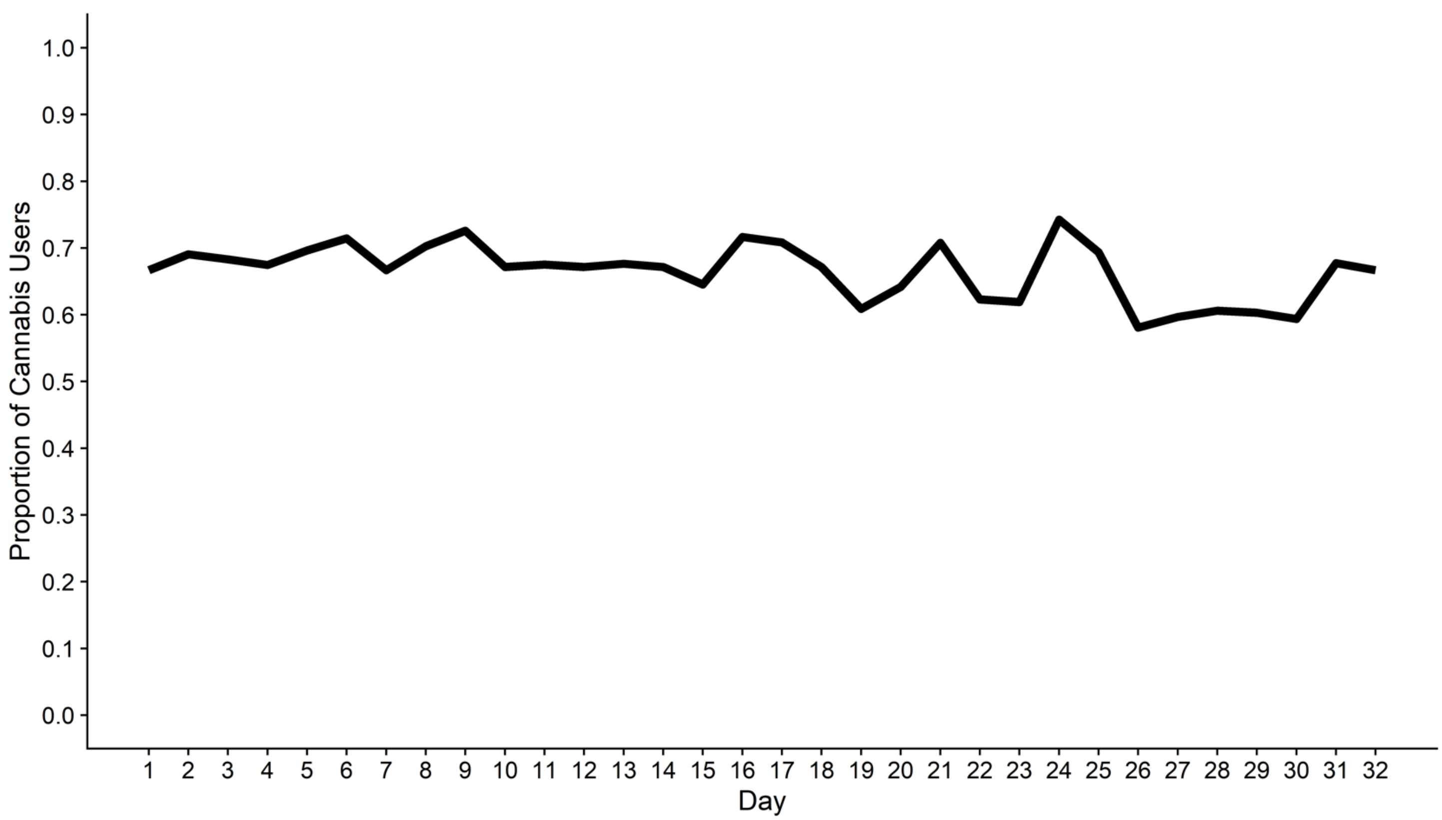
The hurdle model separates results into logistic regression on the zeros and a truncated Poisson model on the non-zero data. Cannabis use did not demonstrate a significant change in usage probability (IRR = 1.01, 95% CI = [0.99, 1.02], p = 0.23; Figure 2) or quantity (IRR = 0.99, 95% CI = [0.98 1.00], p = 0.08; Figure 2) over the 32-day measurement period. The original study narrowed the final sample to N = 69, only including participants with a >70% daily diary completion rate (Joyce, 2019; Joyce et al., 2021). We re-tested model fit for this narrowed sample. Both negative binomial and Poisson models failed to converge, and a Hurdle model with random intercept and slopes again provided the best fit, similar to our model fit for N = 88. Analyses on the narrowed sample demonstrated findings consistent with the full sample (N = 88) for both probability of use (IRR = 1.01, 95% CI = [0.99, 1.03], p = 0.19) and quantity used (IRR = 0.99, 95% CI = [0.98, 1.00], p = 0.10).

It is notable that 83% of the total variance available to be explained was between-subjects (ICC = 0.83), while only 17% was within-subjects. The marginal R^2 = 0.004 further highlighted the small amount of variance accounted for by day of cannabis self-monitoring.

Comparison of Cannabis Measurements: Daily Diary and CTLFB

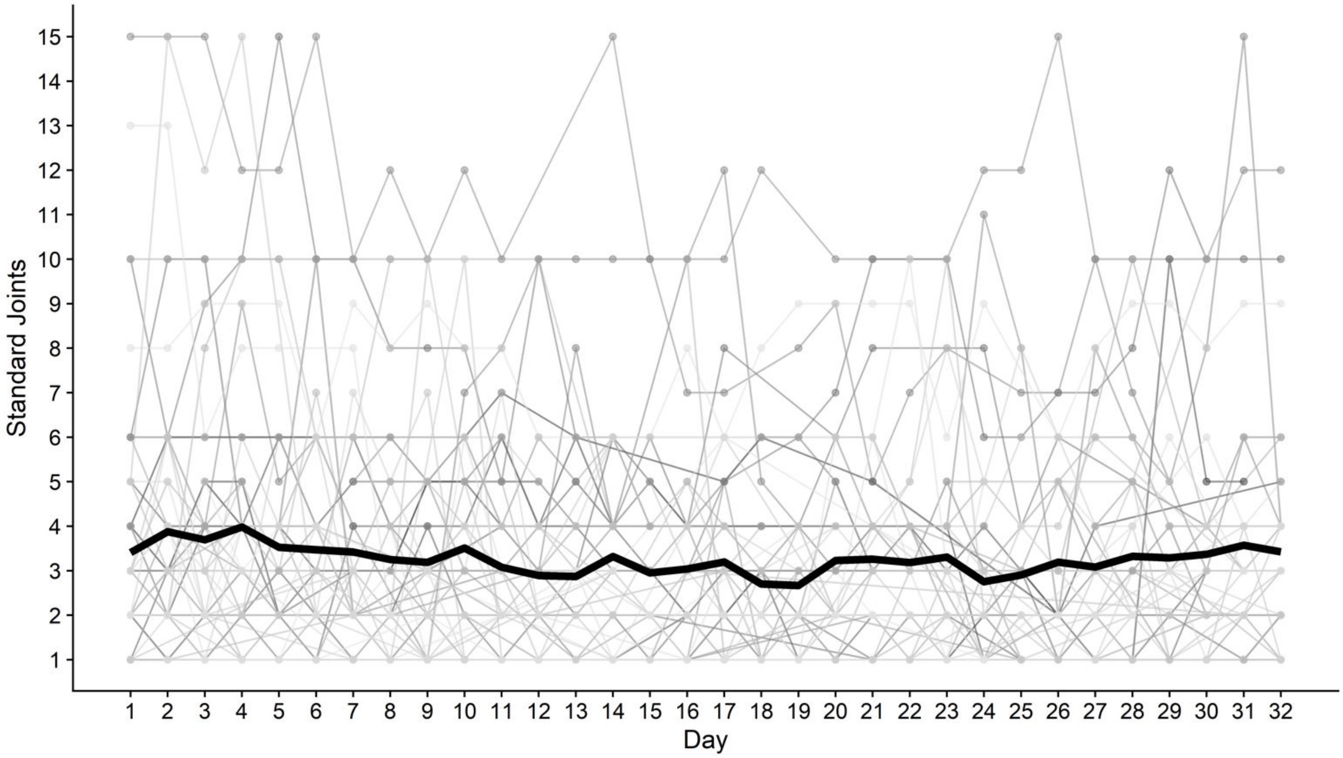
A further set of exploratory research questions arose through peer review. Primary study outcomes were quantity and probability of cannabis recorded using daily diary data; however, participants also estimated 30 prior days of usage on the CTLFB. After discovering zero-inflation in the daily diary data, we compared patterns for both cannabis assessments to explore their similarities and differences.

Figure 2. *Line Plots of Mean Cannabis Use/No Use (Top Panel) and Cannabis Quantity (Bottom Panel)*



(Figure continues)

[3]See supplemental material for the full R code.
[4]See Hu, Pavlicova, and Nunes (2011) for a detailed example of the utility of (and the differences between) negative binomial, Poisson, and Hurdle models.



Note. For the top panel, no use = 0 and use = 1. Results shown over the 32-day study period. The graph demonstrates slightly more occasions of cannabis use as opposed to no use at the outset, with no significant change in probability of usage across the self-monitoring period. For the bottom panel, mean cannabis use quantity is displayed in joint equivalents (on cannabis using days) across the 32-day study period. The mean line is superimposed in black. The graph demonstrates no significant change in daily quantity of cannabis use across the 32-day self-monitoring period.

We sampled the first 30 days of the daily diary data for each participant as a direct comparison to the 30 days reported for the CTLFB (i.e., excluding daily diary days 31-32). Data were aggregated across all 30 days in creating one value per participant ($N = 88$) with four variables of interest: Sum of non-use days (i.e., scores of zero), sum of days with missing data (out of 30), quantity used (per day), and probability of use (a proportion of cannabis use days: cannabis use days / days completed). Wilcoxon signed-ranks tests indicated no significant differences between the daily diary and CTLFB on zero values (Mdn CTLFB = 1, Mdn Daily = 2, $p = 0.13$), quantity used (Mdn CTLFB = 1.7, Mdn Daily = 2.0, $p = 0.12$), or probability of cannabis use (Mdn CTLFB = 0.97, Mdn Daily = 0.93, $p = 0.29$). The CTLFB was found to have significantly fewer missing datapoints than the daily diary data (Mdn CTLFB = 0, Mdn Daily = 3.5, $p < 0.0001$). This is natural given that all 30 days of the CTLFB are completed in a single session. Spearman correlations also demonstrated strong relationships between the daily diary and CTLFB data for zero values ($r = .66$, $p < 0.0001$), quantity used ($r = .82$, $p < 0.0001$), and probability of use ($r = .74$, $p < 0.0001$).

Subjective Reactivity

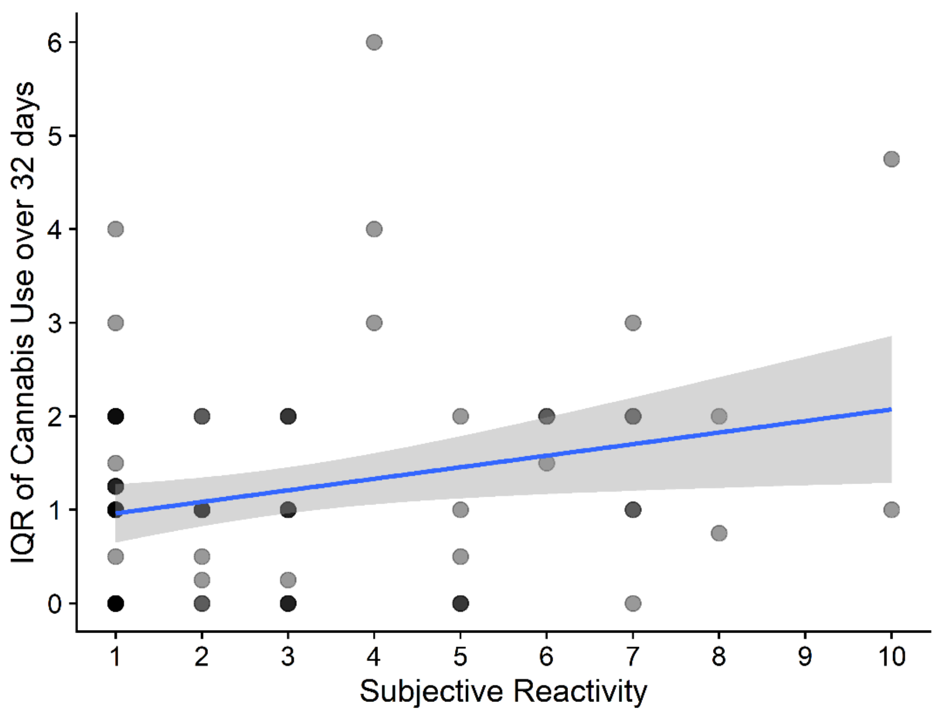
Participants self-reported perceiving mild reactivity of cannabis use to daily self-monitoring of cannabis use behaviors (Median = 2; IQR = 3; Range = 1-10), on average. Six datapoints were missing due to participant dropout. These six participants did not complete the subjective reactivity measure as they did not attend the debriefing, resulting in a sample of $N = 82$. This median represented a score falling between "*not at all*" and "*moderately*". While many participants (45%) reported a "1" on this scale (no reactivity), the majority (55%) reported some degree of subjective reactivity with 24% scoring 5 or higher (at least moderate reactivity).

Subjective Reactivity as a Moderator of Trajectories

The impact of participants' subjective reactivity on objective change in cannabis use over time was investigated with a three-step hierarchical linear regression. In the first step (*N* = 88), time was entered as the only predictor, with results as previously reported (i.e., no significant change in probability or quantity over time). In the second step (*N* = 82), subjective reactivity was entered as an additional predictor. Cannabis still demonstrated no significant change over time for dichotomous use (95% CI OR [0.99-1.02], $p = .29$), and the effect of subjective reactivity was non-significant (95% CI OR [0.90-2.08], $p = .14$). In the count (quantity) portion of the model, time remained non-significant (95% CI IRR [0.98-1.00], $p = .11$) and subjective reactivity was non-significant (95% CI IRR [0.87-1.09], $p = .65$). In the third step (*N* = 82), the interaction (time x subjective reactivity) was explored; the interaction effects were non-significant for the logistic (95% CI OR = [1.00-1.01], $p = .32$) and count (95% CI IRR = [1.00-1.00], $p = .80$) portions of the hurdle model. Thus, we did not find evidence of subjective reactivity as a moderator of the relationship between time and cannabis use.

The relationship between subjective reactivity and day-to-day variability was then investigated using the within-person interquartile range (IQR). That is, IQR for cannabis use was calculated for each participant, and subjective reactivity was regressed on this within-person IQR score. There was a small significant relationship between self-reported subjective reactivity and variability of cannabis use across 32 days (B = .12, 95% CI = [0.02, 0.23], $p = .02$; Figure 3). Thus, greater subjective reactivity signalled greater variability in day-to-day cannabis use.

Figure 3. *The relationship between subjective reactivity and day-to-day variability*



Note. The relationship is demonstrated using the within-person interquartile range (IQR). IQR for cannabis use was calculated for each participant, and subjective reactivity was regressed on this within-person IQR score. This figure demonstrates a small positive relationship between self-reported (subjective) reactivity and variability of cannabis use across 32 days.

DISCUSSION

We are among the first to investigate reactivity to daily self-monitoring of the *quantity* of cannabis use. We examined female users' reactivity to 32-days of twice daily cannabis use self-monitoring. Results demonstrated no significant change in cannabis use over time for either probability or quantity of use.

Findings are similar to those of Buu et al. (2020) who indicated no impact of daily self-monitoring on cannabis use probability or frequency. Prior findings on reactivity to daily self-monitoring of alcohol and tobacco have been mixed, demonstrating reactivity in some cases (e.g., Collins et al., 1998), but not others (e.g., Simpson et al., 2005). Prior research on assessment reactivity for alcohol provides a helpful comparison for our cannabis findings in a related (but distinct) domain of addictive behaviours. Findings for alcohol have been mixed, but nonetheless suggest a pattern of significant reactivity effects among treatment-seeking or treatment-involved samples (e.g., Epstein et al., 2005; Kaminer et al., 2008). However, this pattern has primarily been observed in studies that have investigated reactivity to baseline or periodic assessments as opposed to daily diary measurements. Because participants in our study were not recruited to be treatment-seeking, our sample may not have had sufficient motivation to facilitate change in their cannabis use stemming from self-monitoring. Thus, future research should investigate reactivity to daily self-monitoring among treatment-seeking cannabis users, as results could have important implications for ways to enhance motivation and behavior change for cannabis users in treatment settings. While our sample was not overtly treatment-seeking, almost 60% of participants reported engaging in hazardous cannabis use (as shown in Table 1); therefore, our failure to observe reactivity effects cannot be readily attributed to low levels of problematic use in our sample.

Similar to treatment-seeking status, age has been found to play a primary role in alcohol reactivity, with more research supporting reactivity effects in younger populations (Schrimsher, 2011). Again, it is worth noting that most of the existing research investigating age's role in reactivity has utilized baseline or periodic assessments as opposed to daily diary measurements. Thus, future studies would benefit from exploring the role of age in reactivity to daily self-monitoring (and to periodic/baseline assessment) in the cannabis field. Future research might additionally focus on daily self-monitoring in the context of goal setting as a mechanism for motivational enhancement and behaviour change in cannabis use (Spinola et al., 2017). More research is needed to assess potential differences in reactivity effects between cannabis users who self-monitor with pre-set goals vs. those who engage in self-monitoring alone.

Reactivity has also been shown to fluctuate with factors such as length (Buu et al., 2020) and intensity of measurement (McCarthy et al., 2015). While our study demonstrated no assessment reactivity for cannabis, we build on previous findings by Buu et al. (2020) by demonstrating that among a sample of female participants, reactivity did not seem to exist for cannabis quantity and did not seem to be impacted when frequency of self-monitoring increases to twice per day. It is worth noting that Buu et al. (2020) demonstrated some impact of reactivity on alcohol use, but no impact on cannabis use. The observed difference between alcohol and cannabis was explained as potentially resulting from the focus on frequency of cannabis use. Our study overcame this limitation by including investigation of cannabis use quantity, yet still found no evidence of reactivity to daily self-monitoring of cannabis use.

Following the finding that the pattern of overall cannabis use was zero-inflated, we compared data on our primary outcome measure (daily diary surveys) to reports on a CTLFB (Robinson et al., 2014). Measures of zero scores, along with general cannabis use, were comparable on both measures, thereby strengthening support for the validity of our initial (daily diary) assessment. Missing data was found to be lower on the CTLFB, likely resulting from participants completing the CTFLB on a single occasion. Additionally, less missing data may be explained by a potential tendency for participants to use cognitive heuristics (e.g., "digit bias"; Nagi, Stockwell, & Snavley, 1973) to generate data on the CTLFB for days when they were not sure about their use. Similar reports on both cannabis use assessments indicate that the potential use of such heuristics did not appear to impact accuracy.

This study was the first that we are aware of to examine subjective reactivity to cannabis daily self-monitoring. In general, many participants experienced no subjective reactivity (45%) but there was wide variability in subjective reactivity across the remaining 55%. Furthermore, we conducted a novel examination of the impact of subjective reactivity on objective reactivity to determine the degree to which participants who experienced reactivity were aware of this reactivity. While subjective reactivity did not moderate changes in objective cannabis use over time, participants who reported experiencing greater subjective reactivity exhibited greater within-person variability in cannabis use over time. This seems to suggest that cannabis users may notice and misinterpret day-to-day variability in cannabis use levels as reactivity to self-monitoring. A potentially important implication of this finding may be that those with higher perceived reactivity to self-monitoring may benefit from being matched with interventions that use self-monitoring to help increase awareness of cannabis triggers.

This study has several strengths. First, this was only one of a few studies to investigate reactivity to daily self-monitoring of cannabis use (cf. Buu et al., 2020) and among the first to examine reactivity effects on cannabis use quantity. Additionally, our study included an evaluation of subjective reactivity and examined its impact on both objective reactivity and day-to-day variability in cannabis use over time.

However, our study also had limitations, most of which highlight potentially beneficial future directions. First, with a female-only sample, our findings may not generalize to males (Green, 2006; Tuchman, 2010). However, as females are underrepresented in cannabis research (Schlienz et al., 2017), our sample offers additional representation to females in this regard. Additionally, we were unable to determine the impact of reactivity to daily self-monitoring among treatment-seeking individuals, as our study was not limited to treatment seekers. We also did not measure other potential moderators of cannabis use reactivity to self-monitoring such as perceived desirability/undesirability of cannabis use behaviour, cravings, or motivations to change (Barta et al., 2012; Wray et al., 2014). Future research into relevant moderators can have implications for both treatment-seeking and non-treatment-seeking populations. Each of these variables may contribute to cannabis use behavioural change in the context of daily self-monitoring. Including CUDIT-R scores as an additional moderator might appear meaningful at first glance, but such inclusion would confound predictor with outcome (given that the CUDIT-R includes items tapping cannabis use levels), making results relatively uninterpretable. Moreover, since problems are so strongly related to use (Pearson, 2019), we believe that it would no longer be clear what the outcome measure is in the multivariate model. That is, cannabis quantity with the shared variance of cannabis problems removed would likely not be interpretable as an outcome measure (i.e., conceptually, it is hard to imagine what this might represent).

Future research should additionally consider assessing subjective reactivity prior to objective monitoring (i.e., assessing expectations for reactivity), which would provide additional information on potential individual differences in reactivity susceptibility. Finally, participants were not asked about directionality of subjective change to their cannabis use (i.e., did they perceive their cannabis use to be decreasing or increasing secondary to daily monitoring). By not inquiring about directionality, true relations between subjective and objective reactivity may have been obscured, since the objective reactivity measure, but not the subjective reactivity measure, did allow for quantification of reactivity effects involving (the rarer) increases in cannabis use over time. In future, we recommend that researchers ask not only about the degree of perceived reactivity of cannabis use to self-monitoring, but also the direction of that perceived change (i.e., increase or decrease) rather than simply assuming the perceived change involves a perceived decrease.

Overall, our results suggest daily self-monitoring of cannabis use among females does not significantly impact usage over time, and further suggest that this change is not moderated by subjective reactivity. However, participants who perceived greater reactivity of their cannabis use to daily self-monitoring were more likely to have variable cannabis use over time, though the effect was small. From a research standpoint, reactivity is likely not a major confounding factor in research studying cannabis use with daily diary methods. Clinically, self-monitoring cannabis is unlikely to provide standalone benefits, at least for non-treatment-seeking individuals; however, the clinical utility of daily self-monitoring among treatment-seeking cannabis users has yet to be determined. The present study also raises the possibility that the relationship between subjective reactivity and day-to-day variability in cannabis use might be clinically useful, though further research is needed to establish the applicability of these findings in the clinical context. Future research should consider assessing subjective reactivity prior to objective monitoring (i.e., assessing expectations for reactivity), which would provide additional information on potential individual differences in reactivity susceptibility.

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