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Effects of marijuana use on impulsivity and hostility in daily life

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ABSTRACT

Background: Marijuana use is increasingly prevalent among young adults. While research has found adverse effects associated with marijuana use within experimentally controlled laboratory settings, it is unclear how recreational marijuana use affects day-to-day experiences in users. The present study sought to examine the effects of marijuana use on within-person changes in impulsivity and interpersonal hostility in daily life using smartphone administered assessments.
Methods: Forty-three participants with no substance dependence reported on their alcohol consumption, tobacco use, recreational marijuana use, impulsivity, and interpersonal hostility over the course of 14 days. Responses were analyzed using multilevel modeling.
Results: Marijuana use was associated with increased impulsivity on the same day and the following day relative to days when marijuana was not used, independent of alcohol use. Marijuana was also associated with increased hostile behaviors and perceptions of hostility in others on the same day when compared to days when marijuana was not used. These effects were independent of frequency of marijuana use or alcohol use. There were no significant effects of alcohol consumption on impulsivity or interpersonal hostility.
Conclusions: Marijuana use is associated with changes in impulse control and hostility in daily life. This may be one route by which deleterious effects of marijuana are observed for mental health and psychosocial functioning. Given the increasing prevalence of recreational marijuana use and the potential legalization in some states, further research on the potential consequences of marijuana use in young adults' day-to-day life is warranted.

1. Introduction

Marijuana remains the most commonly used illicit drug (Caldeira et al., 2012) and its use continues to rise, particularly among its most frequent users: young adults (Degenhardt and Hall, 2012; Substance Abuse and Mental Health Services Administration, 2014). Changes in legal status, perceptions of low associated risk and ease of availability of marijuana in social settings have been associated with increased rates of recreational marijuana use (Cerda et al., 2012; Johnston et al., 2013; Palamar et al., 2014). One in five young adults has used marijuana in the past month, and over a third of young adults have used marijuana in the past year. While the negative effects of chronic use of marijuana are increasingly well-established (Volkow et al., 2014; Silins et al., 2014), there are also many young adults using marijuana at sub-threshold levels. Recreational marijuana use, the use of marijuana on one or more occasions without associated use disorders (Moreno et al., 2012), is increasingly prevalent. Further understanding of whether increased recreational exposure to marijuana leads to greater risk for detrimental psychological and behavioral effects is a needed avenue for research.

There is growing evidence that marijuana use has lasting effects on the cognitive and regulatory networks of the brain (Filbey et al., 2009). These effects may increase an individual's susceptibility to the acute effects of marijuana on impulsivity and broader neurocognitive functioning (Martin-Santos et al., 2010; Wrege et al., 2014). Recreational marijuana users report elevated impulsivity traits, impulsive behaviors, and deficits in inhibitory control relative to non-drug users, but similar to binge drinkers (Griffith-Lendering et al., 2012; Moreno et al., 2012). These findings suggest that impulse control deficits may be observable even in those who engage only in recreational use. There is also evidence from experimental methods that marijuana affects impulsivity immediately after administration, including decreases in inhibitory control (McDonald et al., 2003) and measurable changes in risky

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behavior relative to placebo (Lane et al., 2005). However, it is unknown whether recreational marijuana use in daily life elicits similar within-person changes in impulse control.

Marijuana use has also been associated with negative effects on interpersonal interactions. Laboratory studies have found that individuals under the influence of marijuana displayed systematic changes in interpersonal behavior and experience, including a pattern of interpersonal withdrawal, hostility, and diminished interpersonal skills (Janowsky et al., 1979; Roser et al., 2012). Despite subjective reports of enhanced sensation and perception, individuals under acute administration of THC showed objective decreases in the number of interpersonal interactions engaged in and the expression of empathetic communications (Galanter et al., 1974; Janowsky et al., 1979). This suggests that marijuana use has a significant impact on interpersonal behaviors, of which users are not aware. Additional research has found social-emotional deficits in marijuana users (Platt et al., 2010; Roser et al., 2012), and increases in hostility or aggression (Smith et al., 2013). Chronic marijuana users show anterior cingulate cortex (ACC) and amygdala deactivation in response to subconscious presentation of emotional faces, whereas normal controls show increased activation (Gruber et al., 2009). Given that the ACC is involved in error monitoring and behavioral correction/inhibition in response to changes in context or environment, this may manifest as inappropriate interpersonal responses or altered perceptions of interpersonal behaviors in others. However, it is unknown whether these effects on interpersonal behavior and social-emotional processing occur after any marijuana use and whether these changes are observable in interpersonal behavior (e.g., hostility) over the course of daily life.

Research to date has primarily used experimentally controlled laboratory methods to examine associations between marijuana use and impulse control and interpersonal behavior; although valuable, this approach limits generalizability of the findings (e.g., to day to day experiences of individuals in natural contexts). Ecological Momentary Assessment (EMA) is a validated and reliable method to uniquely capture substance use–as well as important social, contextual, and behavioral information in daily life via real-world data collection (Shiffman et al., 2008; Shiffman, 2009; Smyth and Heron, 2012). Frequently implemented via smartphone technology, EMA offers several advantages in examining complex directional relationships by assessing variations in experiences, environmental exposures, and psychological states within and outside the context of drug or alcohol use (Shiffman et al., 2008; Shiffman and Saul, 2009; Shiffman, 2009). These methods improve upon traditional timeline follow-back approaches by capturing intraindividual variability in behaviors and experiences over time, while having minimal impact on behavior (Simpson et al., 2005; Shiffman et al., 2007; Shiffman and Saul, 2009). EMA has been used to monitor alcohol and drug use in community adult and adolescent samples and has been widely used in studies to understand effects of alcohol and drug use, drug craving and relapse outcomes (Shiffman et al., 1997, 2002; Armeli et al., 2000, 2005, 2007; Carney et al., 2000; Chandra et al., 2007; Mermelstein et al., 2007; Weinstein et al., 2008; Todd et al., 2009).

Despite increases in use of marijuana, very little research has examined the real world effects of recreational marijuana use on daily experiences. Several studies have used daily diary methodology to examine psychological states as predictors of marijuana use in regular users (Buckner et al., 2011, 2012a,b). Research with regular marijuana users has found that retrospective reports of frequency of use are highly unreliable in predicting moment to moment use (Hughes et al., 2014). These findings point to the utility and validity of assessing marijuana use using EMA methods. However, less work has been done using this methodology to examine the potential behavioral and psychological effects of marijuana use on real world outcomes in recreational marijuana users.

Table 1
Sample demographics and descriptives.

Age	23.7 (4.6)
Female	60.5% (26)
Education years	15.3 (2.0)
Currently enrolled in post-secondary education	65.1% (28)
Race/Ethnicity	
Caucasian	65.1% (28)
Hispanic	16.3% (7)
Asian	14.0% (6)
African-American	4.7% (2)
Drug screening	
Cotinine positive	4.7% (2)
Tetrahydrocannabinol positive	20.9% (9)
Carbon monoxide level >6	7.0% (3)
Average number of use days in last 30 days	
Marijuana use days	4.5 (8.3)
Alcohol use days	9.6 (5.2)
Tobacco use days	1.5 (4.6)
Mean daily variable scores	
Marijuana use days	.18 (.38) [0–1]
Alcohol use days	.40 (.49) [0–1]
Impulsivity score	30.2 (14.6) [0–79.3]
Hostility (self)	20.3 (12.4) [0–78.8]
Hostility (other)	20.5 (11.4) [0–82.0]

Percentages (frequency) and mean (SD) and [ranges]. $N = 43$.

The purpose of this study was to examine the effects of marijuana use on same day and subsequent day reports of impulsivity, interpersonal behavior, and interpersonal perceptions using EMA. Based on prior findings from experiments in which marijuana was administered and behavioral changes were observed, we hypothesized that marijuana use would acutely increase impulsivity (i.e., a diminished ability to focus on or persist in tasks and a tendency to act on the spur of the moment without planning) and hostile interpersonal interactions (i.e., perceptions of self or other as distant, unfriendly, cold, disagreeable or quarrelsome) in day-to-day life.

2. Method

2.1. Sample

The sample consisted of 43 men and women, who reported prior recreational marijuana use, currently consumed alcohol at least once per week, and were not substance dependent or currently using substances other than nicotine, marijuana, or alcohol. Participants were recruited for a larger study on social and hazardous drinking, which used flyers and pamphlets distr buted at high traffic locations and community events, word of mouth, and ads posted on Craig's List. Ads requesting inquiries from social drinkers, regular drinkers, or individuals interested in reporting experiences using a smartphone for a research study. Demographics and descriptives are presented in Table 1.

2.2. Procedures

Respondents initially completed a phone screening and were excluded if they did not drink at least once per week for the last month, were substance dependent for any substance except nicotine or had a serious mental illness (schizophrenia, bipolar disorder, psychotic disorder). This study was approved by the human subjects research committee and written informed consent was obtained prior to intake.

Following the phone screening, participants completed an intake interview that verified eligibility criteria using SCID-I diagnostic interviews (First et al., 1996) and gathered demographic and substance use history. Participants completed carbon monoxide test (Pico Smokerlyzer) and provided urine samples (Innovacon Integrated E–Z Split Key 6 Panel Cup II; Reditest cotinine test device). They returned for a 1 h training session on how to use and complete the items on the smartphone assessments prior to commencing 14 consecutive days of reporting. Participants could initiate event-contingent surveys (e.g., interaction or substance use) at any time. Reminders to complete the end of day survey were triggered on the phones every evening at 9:30 pm but could be completed at any time in the evening when activities were done for the day and prior to going to bed. Responses were uploaded to a secure server in real time and back-ups were saved on the devices. Research assistants monitored compliance daily and subjects were contacted if irregularities were identified or surveys were not completed. At the end of participation, data saved on the phones was then uploaded and verified against data sent in real time

to the server to ensure the completeness of response datasets. Participants were paid for their participation and received a bonus payment for 95% compliance with survey responses.

2.3. Measures

2.3.1. Daily alcohol, tobacco, and marijuana use. Alcohol, tobacco, and marijuana use were collected in real-time by an event-contingent survey. Participants initiated reports on how many drinks of alcohol they consumed, how many hits of marijuana and the method of intake, and how many cigarettes or cigars they had used. Participants were also reminded during the course of other surveys to report any substance use not previously reported. For the purposes of this analysis, substance use was coded as yes/no if a participant reported any use that day.

2.3.2. Daily impulsivity. Impulsivity was assessed during the end of day survey using the Barratt Impulsiveness Scale-Brief (Steinberg et al., 2013), a 7-item short form of the BIS-11 that measures general impulsiveness. Items were altered slightly to give the participant a daily context for the response. For example, "I do things without thinking" was "Today, I did things without thinking." The response format used a visual analog scale (VAS) ranging from "Never" to "Always" and participants' touch responses to each item were recorded by the smartphone on a scale from 0 to 100. Reverse-scored items were re-coded and item scores were then averaged for a scale score.

Given that the BIS-B was originally created to detect between subjects, not within-subjects, differences in impulsivity, we calculated reliability for the measure using coefficient omega (Geldhof et al., 2014) in a multilevel confirmatory factor analysis in Mplus (Muthén and Muthén, 2011), a more appropriate approach for examining reliabilities with hierarchical data (McDonald, 1999). Reliability for both between and within-subjects impulsivity measures was good to excellent: $\omega = .961$, and $\omega = .776$, respectively.

2.3.3. Daily interpersonal hostility. Participants completed a survey every time they had an interpersonal interaction that lasted longer than 5 min (minimum of 4 interaction assessments per day). The majority of surveys were completed immediately at the end of the interaction and 99% of the surveys were completed within 2 h of the interaction. Consistent with prior research methods measuring interpersonal behavior and perceptions within an interaction (Roche et al., 2014), participants were asked two questions about "rate how the *other person* acted during the interaction" and "rate how *you* acted during the interaction" on a 0–100 VAS ranging from distant to friendly. Prior to the start of the field study, participants were trained on rating examples of hostile and affiliative interpersonal behaviors. Higher scores represent greater hostility. Ratings from the interaction surveys completed over the course of the day were then averaged to create a daily interpersonal behavior variable and a daily interpersonal perception variable.

3. Results

Data in these analyses consisted of 43 participants × 14 days = 602 observations. There was 4% missing data on the BIS-B across all measurement occasions and less than 1% missing data on interpersonal interactions (38 and 3 missing, respectively of 602 possible values). We estimated multilevel models predicting within-person fluctuation in daily reports of impulsivity and interpersonal hostility.

3.1. Data analytic strategy

All analyses were conducted using the MIXED procedure in SPSS, which accounts for the interdependence associated with multiple repeated measures within the same individual. Models were estimated using restricted maximum likelihood estimation (REML), and a first-order autoregressive covariance structure was used to account for autocorrelation in the repeated measures.

3.2. Analyses

We first confirmed that there was significant within-person variability in outcomes across the 14 days by estimating unconditional models for impulsivity and interpersonal hostility. These models decomposed the variance due to between-subjects variability (variation due to individual differences across the sample) versus within-subject variability (variability within a subject's ratings over the 14 days relative to his or her own average). Intraclass correlations, or the proportion of variation due to within-person fluctuations, were .45 for ratings of others' hostility, .47 for ratings of one's own hostile behavior, and .56 for impulsivity ratings. Results confirmed that there was statistically significant variability within-subjects over the 14 day period in each of the dependent measures: impulsivity, $\tau_{00} = 98.38$, $p < .001$, reports of others' hostility, $\tau_{00} = 74.05$, $p < .001$, and reports of their own hostility $\tau_{00} = 83.11$, $p < .001$. This supports the addition of predictors to the models to explain systematic variation in all three outcome measures.

Our primary predictor of interest was within-person marijuana use, coded as a dichotomous variable, where a value of 1 indicated marijuana use on a particular day, and a value of 0 indicated no use. This approach models the associated effect of *any* marijuana use rather than modeling the dose-response effect. Dose in marijuana may vary considerably, depending on source, route of administration and context of use, between and within users in real-world environments (Temple et al., 2011). Thus, modeling any-use reflects a more conservative examination of marijuana use effects in daily life.

3.2.1. Variable centering. We separated within-subjects fluctuations in marijuana use from between-subjects differences in marijuana use, to ensure that within-subjects process results were not contaminated by between-subjects differences. The within-subjects marijuana use variable was person-mean centered (Curran and Bauer, 2011). We also included a linear time trend that was mean centered and scaled to units of weeks to account for any unexpected effects of the passage of time on the outcomes (Bolger and Laurenceau, 2013). With these centering choices, intercepts in this model reflect the estimated value of the outcome for the average participant, on an average day, at their personal average level of marijuana use.

3.2.2. Covariates. Age and gender were sample-centered and included as covariates in all three models. Given the potential effects of alcohol consumption on impulsivity and interpersonal behavior, within-person drinking on the same and prior days and a between-subjects variable capturing average drinking days across the study were included as controls in all models. Models also included mean tobacco cigarettes smoked per day throughout the study period. Finally, we added an indicator variable controlling for weekend.

3.2.3. Model. The same model was used for each of the three outcomes. We present the equation for impulsivity (BIS-B) to illustrate the model.

$$\begin{aligned}\text{BIS}-\text{B} = {} & \gamma_{00} + \gamma_{01} \times (\text{MJ\_Use}_{\text{Avg}}) + \gamma_{02} \times (\text{Age}) + \gamma_{03} \times (\text{Gender}) \\ & + \gamma_{04} \times (\text{Alc\_Use}_{\text{Avg}}) + \gamma_{05} \times (\text{Cig\_Use}_{\text{Avg}}) \\ & + \gamma_{10} \times (\text{MJ\_Use}_{t}) + \gamma_{20} \times (\text{MJ\_Use}_{t-1}) \\ & + \gamma_{30} \times (\text{Time}) + \gamma_{40} \times (\text{Weekend}) \\ & + \gamma_{50} \times (\text{Alc\_Use}_{t}) + \gamma_{60} \times (\text{Alc\_Use}_{t-1}) + u_0 + r\end{aligned}$$

The intercept (γ_{00}) represents the predicted impulsivity rating when all other predictors are zero. Between-subjects variables, in order, represent average marijuana use, participants' age, gender, average alcohol use, and average cigarette use (γ_{01}–γ_{05}). The remaining gammas represent all within-person predictors. Same-day predictors are indicated by the subscript (t), and lagged predictors by the subscript ($t-1$). Within-subject predictors (γ_{10}–γ_{60}), in order, represent: same-day marijuana use, prior day marijuana use, a variable controlling for the passage of time in the

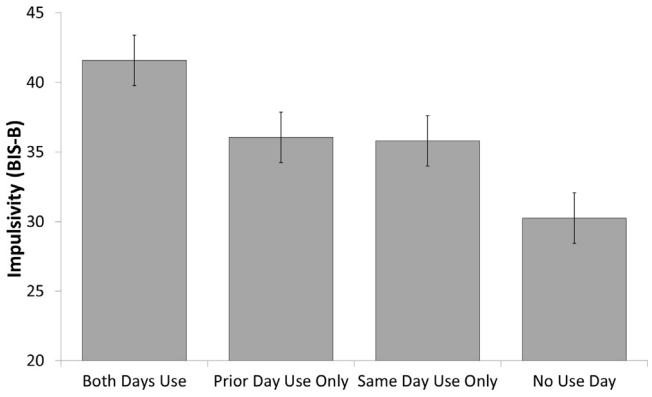

Fig. 1. Within-person changes in impulsivity on days of marijuana use relative to non-use days.

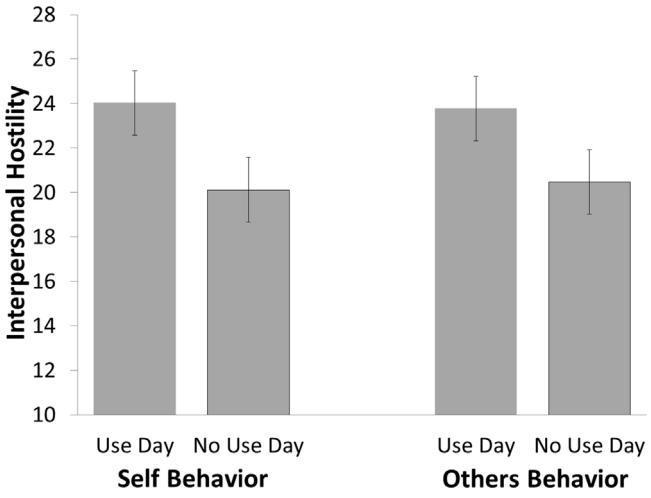

Fig. 2. Within-person changes in hostile behaviors and perceptions on days of marijuana use relative to non-use days.

study, an indicator variable controlling for weekend, versus weekday, differences in impulsivity, same day alcohol use, and prior day alcohol use. Finally, a random effect (u_0) allowed for each participant to have a unique regression equation predicting impulsivity, and a residual term (r) capturing measurement error. We chose an autoregressive covariance structure for residuals, which allows the residuals from proximal days to be more similar than those from more distant days. This consideration is of utmost importance in intensive longitudinal designs, given measurements occur in such close proximity (Bolger and Laurenceau, 2013) and allows for temporal carryover – the possibility that events on one day impact the outcome not only on that day, but on the following day as well (Wickham and Knee, 2013). Following this modeling framework, we can make directional claims about any effects on lagged predictors, because the model controls for same day associations between the predictor and outcome, and establishes the lagged predictor as antecedent to this process (Wickham and Knee, 2013).

3.3. Marijuana use on same day and next day impulsivity

Column 1 of Table 2 presents all relevant statistics from this model. Marijuana use was associated with increased impulsivity on the same day, even when accounting for all other variables. That is, on days when subjects smoked marijuana, versus days when they did not, their impulsivity was significantly higher than usual. Similarly, the prior day's marijuana use predicted significantly increased impulsivity the next day, when compared to within-person impulsivity on days without marijuana use (see Fig. 1). Importantly, average marijuana use (capturing between subjects differences), was not significantly associated with impulsivity, supporting the unique value of within-person daily reporting methods. No other variables were significantly associated with impulsivity. In order to better understand the potential temporal carryover processes, we tested the reverse direction effect of prior day impulsivity leading to next day marijuana use. Negative binomial multilevel models were estimated in SPSS using the GENLINMIXED procedure, with marijuana use as the dichotomous outcome. All control variables were included in the models except for the drinking variable, given that including alcohol in the model would restrict estimated effects to marijuana use only on days in which alcohol was not consumed. Results from these models indicated that prior day impulsivity was *not* predictive of daily marijuana use ($b = .016$, $p = .131$, OR = 1.016), Thus, marijuana use was associated with significant increases in next day impulsivity, but not vice versa.

3.4. Marijuana use with interpersonal hostility

The next model tested whether marijuana use was significantly associated with self-rated hostile behaviors in interpersonal interactions. See column 2 of Table 2 for all relevant statistics and Fig. 2. There was a significant association between same day within-person marijuana use and ratings of one's own hostile behavior the same day, but no significant association was found for prior day's marijuana use. Average marijuana use across the study period was not significantly associated with greater interpersonal hostility. The time trend was also significant, indicating that participants reported less hostility as the study progressed. No other variables were significantly associated with interpersonal hostility.

3.5. Marijuana use with perceived interpersonal hostility

The final model tested whether day-to-day marijuana use was associated with perceptions of hostility *in others* during interpersonal interactions. See Table 2 column 3 for statistics from this model. Results indicated a similar pattern of findings as the ratings of one's own hostility. Same day marijuana use was associated with increased perceptions of interpersonal hostility in others as compared to the same person's perception of interpersonal hostility in others on non-marijuana use days (see Fig. 2). This effect on perceptions of others' hostility was not found for the prior day's marijuana use. Average marijuana use across the study period was not significantly associated with perceptions of greater hostility in others. Ratings of hostility in others declined significantly as the study progressed. There were no other significant fixed effects.

3.6. Effect sizes

There is no consensus among researchers on how best to calculate effect size for multilevel models (Peugh, 2010). Thus, we calculated proportion reduction in variance explained as our measure of local effect size by comparing within-person outcome variance from models with marijuana use predictors to models with all controls but no marijuana use predictors. We found that marijuana use accounted for a small proportion reduction in the outcome variance (other hostility .6%, self-hostility .9%, and impulsivity 2.6%).

Table 2
Models of daily marijuana use as a predictor of impulsivity and hostility.

	Impulsivity		Hostility (self)		Hostility (other)	
	Estimate (SE)	*p*	Estimate (SE)	*p*	Estimate (SE)	*p*
Fixed effects						
Intercept	30.25 (1.81)	**<.001**	20.12 (1.45)	**<.001**	20.48 (1.32)	**<.001**
Same day marijuana use (within-person)	5.55 (1.72)	**.001**	3.91 (1.51)	**.010**	3.30 (1.43)	**.021**
Prior day marijuana use (within-person)	5.80 (1.69)	**<.001**	−2.11 (1.48)	.155	.50 (1.40)	.720
Aggregate marijuana use (between-person)	7.09 (6.86)	.308	5.44 (5.49)	.328	2.74 (4.98)	.585
Time	.18 (.12)	.118	**−.29** (.10)	**.004**	**−.31** (.09)	**.001**
Weekend	.05 (.96)	.962	−.30 (.86)	.726	−.56 (.81)	.494
Age	−.55 (.40)	.170	.28 (.32)	.381	.18 (.29)	.525
Gender	1.57 (3.66)	.430	1.99 (2.93)	.502	1.74 (2.66)	.517
Same day alcohol use (within-person)	.14 (.93)	.884	−.51 (.84)	.545	−.85 (.80)	.287
Prior day alcohol use (within-person)	.98 (.91)	.281	−.13 (.83)	.874	.41 (.78)	.598
Aggregate alcohol use (between-person)	−4.82 (9.64)	.620	−2.20 (7.71)	.777	5.29 (7.01)	.846
Cigarettes	−1.58 (2.14)	.465	−1.79 (1.71)	.301	−1.48 (1.55)	.349
Random effects						
Level 2, τ_{00}	121.32 (30.43)	<.001	76.52 (19.49)	.001	63.06 (16.08)	.001
Level 1, σ^2	95.158 (6.30)	<.001	81.00 (5.10)	<.001	71.83 (4.46)	<.001
Autocorrelation	.17 (.05)	.001	.12 (.05)	.014	.08 (.05)	.079

Significant effects are presented in bold for $p < .05$.

4. Discussion

This study is the first to examine the effects of marijuana use on changes in impulse control and interpersonal hostility in daily life. The present findings indicate that *any* marijuana use, independent of alcohol consumption, was associated with same day increases in impulsivity, one's own hostile behaviors, and perceptions of hostility in others. In addition, any marijuana use predicted next day increases in impulsivity. Associations between marijuana use and increased impulsivity and hostility are relative to one's own behavior on days in which marijuana was not used and are not attributable to individual (between-subject) differences such as age, average marijuana use or history of substance use.

Our findings support a directional effect of marijuana use on increases in next day impulsivity, a result not previously described in the literature. This is consistent with prior research findings that occasional users of marijuana experience stronger effects of marijuana on attention and inhibition relative to chronic users (Theunissen et al., 2012). Impulsivity is associated with increased risk for mental health issues, addiction disorders, and engagement in risk behaviors (Potenza and de Wit, 2010; Dawson et al., 2012; Stautz and Cooper, 2013; Gullo and Potenza, 2014) and prior research on acute marijuana use effects has found increases in risk behaviors (Lane et al., 2005). Thus, changes in impulsivity following marijuana use may increase vulnerability for self-regulation deficits and increase propensity for risky or problematic behaviors. These changes may underlie some of the previously observed effects of marijuana use on long-term psychosocial functioning (Silins et al., 2014).

The present findings suggest that days on which marijuana use occurs are also associated with increases in impulsivity and interpersonal hostility relative to days on which marijuana use did not occur. Hostility has been associated with cardiovascular risk, stress related health dysfunction, troubled intimacy (Smith et al., 2004). In addition, hostile attribution biases, or the tendency to attribute hostility in others, have been linked to aggressive behaviors, particularly relational aggression, across the lifespan (Dodge, 2006; Murray-Close et al., 2010). Systematic increases in perceptions and enactment of hostile behavior would potentially have detrimental impacts on a marijuana user's social network. The observed associations between hostility and marijuana use are consistent with prior literature identifying social-emotional processing issues in marijuana users (Platt et al., 2010; Roser et al., 2012), and may partially explain reports of increased paranoia in vulnerable individuals who use marijuana (D'Souza et al., 2005; Roser et al., 2012). Due to timing of assessments, we cannot definitely determine the ordering of these effects within the same day. It may be that increases in interpersonal hostility, both in others and in one's own behavior, act an acute stressor that motivates marijuana use. Similarly, acute decreases in impulse control may lead to recreational marijuana use. Alternatively, acute effects of marijuana may increase interpersonal perceptions of hostility, hostile interpersonal behaviors, and increase impulsivity in daily life after use. These may also be bidirectional processes that additively increment risk throughout the course of the day. Further research employing laboratory controls and additional measurements of social cognition are needed to determine if interpersonal processing is altered while under the influence of marijuana. Further research should also examine more fine grained momentary assessments, e.g., the Momentary Impulsivity Scale (Tomko et al., 2014), to elucidate the exact timing of changes in impulsivity and hostility relative to use.

The significant effects of marijuana use on the dependent variables accounted for 1–3% of the variability in day to day impulsivity and hostility. Note, however that these apparently small effects

are not comparable to traditional measures of effect size, such as Cohen's d or η_2 (Peugh, 2010). Therefore, even this small degree of change could have clinically meaningful differences. Further, these fluctuations represent incremental changes from day-to-day during a very brief period of use. Longer term impacts on impulsive behaviors and interpersonal functioning should be assessed in future studies using longitudinal study designs.

Interestingly, effects of alcohol use on impulsivity or hostility were not observed in this sample, despite prior studies which have demonstrated this effect (Barthelmes et al., 2010; Reed et al., 2012; Rose et al., 2014). However, other studies have also failed to find alcohol effects on risk-taking behavior (Peacock et al., 2013). We did observe a significant time trend for the interpersonal hostility variables. Although other studies have found that EMA methods do not generally result in systematic changes in the behavior being studied (i.e., reactivity), it is increasingly common that smartphone applications are being developed to promote behavior change through self-monitoring (Heron and Smyth, 2010). Asking participants to rate their own behaviors may have promoted a level of self-awareness that subsequently impacts either interpersonal behaviors or ratings of behaviors. A similar effect has been found in the mindfulness literature. Individuals who were rejected who also underwent a mindfulness intervention behaved with less hostility following the interaction (Heppner et al., 2008). Although this method for assessing interpersonal interactions has been previously used without detectable reactivity effects (aan het Rot et al., 2008; Russell et al., 2010; Roche et al., 2014), future research should examine whether self-monitoring of interpersonal behaviors results in differences in actual behaviors.

Between subjects effects for impulsivity were not observed for those who used more often. While this may be attributable to limited power in the sample to observe between subject effects, this is not unexpected given the focus on recreational marijuana users. Between subjects differences in impulsivity or hostility may only be observed when comparing across use groups (user versus non-users) or when comparing recreational to dependent users. It is also possible that previously observed differences in impulsivity between marijuana users and non-users may be partially explained by the observed within-persona effects of marijuana use. That is, proximal state changes in impulsivity associated with marijuana use may manifest as more trait like differences as use occasions occur more frequently and chronically. Additional longitudinal research is needed to test whether the observed within-person processes progressively lead to higher impulsivity in general.

This study benefited from its ecologically valid design and from the powerful within person analysis which provides statistical directional modeling of responses in daily life. However, this design also was associated with certain limitations. Reporting was dependent on the participant's completion of the surveys and we did not independently verify marijuana or alcohol consumption through daily urine or Breathalyzer assessments, although urine tests were conducted during sessions in the laboratory. However, participants did receive reminders to complete the surveys and missing data in daily surveys was very low (<4%) suggesting that compliance across surveys was high. In addition, individuals may have been intoxicated while completing the surveys and this may have biased the responses for same day effects. Future research should examine whether level of intoxication changes these effects. The sample was predominantly Caucasian and enrolled in some form of post-secondary education or training. Sampling of African Americans was particularly low. Thus, these findings may not generalize to all minority samples or to individuals who do not enroll in college or technical school. These were recreational users and the observed effects of marijuana use may be different for dependent users. However, the significance of finding effects in recreational users highlight the potential impact that the increasing rates of occasional use in the population may have on impulse control and interpersonal processes in daily life.

Marijuana use is associated with increases in impulsivity and hostile interpersonal behaviors in self and others in daily life. The present findings highlight the potential impact of any marijuana use on day-to-day psychological processes and the potential adverse effects to psychosocial function in recreational marijuana users. This has important implications when considering the rising prevalence rates for marijuana use (Substance Abuse and Mental Health Services Administration, 2014), particularly among young adults. Prevention of adverse effects from marijuana use may need to address the potential for short-term interpersonal and cognitive effects following recreational use among users who have typically been considered low-risk (Palamar et al., 2014). Further research is warranted to assess the impact of marijuana use on daily experiences and how these changes may potentiate more chronic adverse outcomes for recreational users.

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Contributors

E.B.A. developed the aims of the study, conducted data analysis, performed literature reviews, and drafted the manuscript. H.B.L. conducted the statistical analysis and drafted the manuscript, M.J.R. assisted with data management and statistical analysis and contributed to manuscript writing, R.S. provided critical feedback, assisted with interpretation of the results, and contributed to the manuscript draft. All authors have contributed to and approved of this manuscript.

Conflict of interest

No conflict declared.

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