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Affect and cannabis use in daily life: a review and recommendations for future research

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Abstract

Background: Although cannabis is often used for the purposes of relieving negative affective states such as anxiety and depression, the associations between cannabis use and affect in daily life are unclear. Ecological momentary assessment (EMA) has been used to study these associations in individuals' natural environments, providing more ecological validity, minimizing retrospective bias, and allowing for the analysis of within-individual processes over time. This review focuses on studies that utilized EMA to examine daily-life associations of cannabis use and negative and positive affective states.

Methods: We review the findings of the 19 articles that met inclusion criteria, including clinical and community samples.

Results: Results provide equivocal evidence regarding relations between cannabis use and affect for community samples. Findings are mixed for clinical samples as well, but more consistent patterns emerge for general negative affect (NA) and anger/hostility at the momentary level; cannabis use may be more likely following increased NA and lead to decreases in NA and anger/hostility in psychiatric populations.

Conclusions: Findings support a negative reinforcement hypothesis for clinical samples in terms of general NA and anger/hostility. However, discrepancies among studies point to a need to thoroughly characterize samples, consider motives for and expectancies of use, improve

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Contributors

A. M. Wycoff and T. J. Trull conducted literature searches. A. M. Wycoff provided summaries of the relevant studies. A. M. Wycoff and T. J. Trull wrote the first draft of the manuscript. J. Metrik contributed to subsequent drafts of the manuscript. All authors approved of the final manuscript before submission.

Conflict of Interest

No conflict declared.

quantification of cannabis use, and consider co-use with other substances. Additional design recommendations are also offered for future studies.

Keywords

Cannabis; Marijuana; Ecological Momentary Assessment; Negative Affect; Positive Affect

1. Introduction

Cannabis is a commonly used drug in the United States and worldwide, with many individuals specifically using cannabis for mood regulation purposes. Furthermore, cannabis use has been associated with psychiatric disorders characterized by affective problems, cross-sectionally (e.g., Cougle et al., 2015; Metrik et al., 2016) and longitudinally (especially heavy cannabis use; Lev-Ran et al., 2014). The idea of using cannabis to alleviate negative mood states goes back hundreds of years (Lee, 2012; NASEM, 2017) and, indeed, a common reason endorsed for cannabis use today is to relieve symptoms of depression and anxiety (Osborn et al., 2015; Walsh et al., 2017). For example, among medical cannabis patients, relief of anxiety and depression are the most common reasons besides pain relief for seeking cannabis (Bonn-Miller et al., 2014; Davis et al., 2016; Metrik et al., 2018; Reinarman et al., 2011; Walsh et al., 2017). Anxiety and depression are also among the most commonly endorsed motives for cannabis use among individuals who use cannabis recreationally (Osborn et al., 2015). This is particularly concerning because of the high comorbidity of cannabis use disorder and mood and anxiety disorders, indicating potential contributions of negative mood states to cannabis use or vice versa (Agosti et al., 2002; Chen et al., 2002; Conway et al., 2006; Cougle et al., 2015; Kevorkian et al., 2015; Lev-Ran et al., 2014; Metrik et al., 2016; Stinson et al., 2006).

Consistent with the *affective-motivational model of drug addiction* (Baker et al., 2004), individuals with affective psychopathology are particularly likely to rely on cannabis use to acutely reduce situational negative affect (Haney et al., 1999; McDonald et al., 2003; Metrik et al., 2011; Phan et al., 2008) or to attenuate withdrawal symptoms (Budney et al., 2003). Using cannabis, for this reason, may thus be negatively reinforcing for individuals who are particularly sensitive to uncomfortable psychological states (Farris et al., 2016).

Cannabis may also be used to heighten positive affect and become positively reinforcing (Cooper and Haney, 2008). However, positive subjective effects are most relevant in the initiation and progression to regular drug use, while negative reinforcement becomes increasingly salient at higher and more frequent levels of use (Robinson and Berridge, 2003). As drug dependence develops, long-term neuroadaptations in the brain occur that underlie the progression from positive to negative reinforcement once the withdrawal/negative affect stage of the addiction cycle sets in (Koob and Volkow, 2010). Therefore, positive reinforcement effects might be more salient for individuals who use cannabis recreationally and are not dependent, while negative reinforcement might be most evident for individuals who are dependent.

Cannabis is a pharmacologically complex drug that can acutely produce both positive and negative subjective effects. Although there are many active constituents in cannabis, the two

cannabinoids that have been isolated and studied the most are Δ9-tetrahydrocannabinol (THC) and cannabidiol (CBD). THC is the psychoactive and major mood-altering constituent in cannabis, and THC content in cannabis plants has risen dramatically over the last few decades, from ~3-5% to up to ~25% today (Mehmedic et al., 2010). Importantly, research suggests a dose-dependent effect of THC on depression and anxiety; lower doses tend to have antidepressant and anxiolytic effects, whereas higher doses may induce depression and anxiety (Mechoulam and Parker, 2013; Metrik et al., 2011, 2015; Morgan et al., 2012; Niesink and van Laar, 2013). Discrepancies between reported uses of cannabis and its potential effects suggest a need for newer approaches to evaluate under what conditions cannabis alleviates or exacerbates negative mood states and psychiatric symptoms.

Research on the effects of cannabis on affect outside the laboratory can provide a more ecologically valid depiction of the way individuals use cannabis and how it affects their emotional state in concert with other daily-life cues. Ecological momentary assessment (EMA; Stone and Shiffman, 1994) is an important research tool that minimizes retrospective biases while gathering ecologically valid data from daily life. EMA (1) is idiographic, allowing for the examination of individual processes like affect or emotion; (2) involves collecting data in real-world environments, increasing the ecological validity of findings; (3) focuses on individuals' current/recent states or behaviors, and collects multiple assessments of each over time, typically several times per day; and (4) can be event-based (initiated by the individual based on instructions), time-based, randomly-prompted, or combinations of these (Trull and Ebner-Priemer, 2013). In addition, EMA data can be analyzed at different levels, allowing for more precision in identifying associations. For example, in studies that include multiple assessments each day, for multiple days, analyses can reveal *momentary effects* (concurrent associations at the moment), *day effects* (average-day score associations), and *person-level effects* (average score across all assessment occasions). Simultaneously entering predictors at multiple levels of analysis can help determine whether momentary or day-level predictors provide meaningful information above and beyond trait-like person-level predictors. Therefore, EMA can provide a fine-grained and ecologically valid picture of the associations between cannabis use and affect.

We review existing EMA studies of the associations between cannabis use and negative affect (NA), positive affect (PA), and a range of subtypes of NA that are related to psychiatric symptoms. In addition, because both theory (e.g., Robinson and Berridge, 1993; Berridge and Robinson, 2016) and research suggest that mood-altering effects of cannabis may depend on the nature of the sample (clinical versus non-clinical; e.g., Haney and Evins, 2016), we organize study results based on whether participants were sampled from the community (and thus, presumably, not endorsing clinical levels of mood and anxiety symptoms or other forms of psychopathology as a whole) or from clinical samples comprised of those with significant levels of psychopathology. Although associations between cannabis use and affect might vary depending on the chronicity of cannabis use and/or presence of cannabis use disorder, most studies did not clearly describe the samples or analyze data separately by CUD. Thus, we were unable to systematically organize the review by the presence of CUD.

At the momentary level, we hypothesized that across all samples, NA would be elevated prior to cannabis use and lower following cannabis use. We expected PA to be elevated during and following cannabis use, and we expected this to be stronger for community samples. We did not make a hypothesis about momentary PA prior to cannabis use because it is possible that elevated PA would precede use as an anticipatory effect, but it is also possible that low levels of PA would precede use if individuals use cannabis for the purposes of increasing PA. We generally did not expect positive or negative associations between cannabis use and affect at the day level because it is often difficult to establish temporal precedence at this level of analysis. If temporal precedence were adequately established, we would expect the same pattern of findings that we expect at the momentary level. Given that person-level predictor's approximate trait-level measures, we expected positive associations between NA and cannabis use across samples, with stronger associations in clinical samples.

2. Methods

We searched the PubMed and Psyclnfo databases to identify relevant studies up until December 2017. The search combined the terms *cannabis or marijuana* with the following: *ecological momentary assessment, experience sampling method, ambulatory assessment, ambulatory monitoring, electronic diary, daily diary, daily life, daily lives, and interactive voice response.* Next, manual searches of Google Scholar and Research Gate were conducted based on authors of articles already identified. Lastly, an additional manual search was completed of abstracts listed on the webpage for the *Society for Ambulatory Assessment*. Studies were included if they used any form of EMA (paper, electronic diary, smartphone) to empirically examine relations between cannabis use and mood/affective states. Specifically, these studies needed to ask participants explicit questions about cannabis use and affective states during the EMA period. In total, 19 articles from 15 separate studies are included in this review.

Table 1 provides an overview of these studies, which are listed alphabetically. The table is organized to highlight: (1) the *nature of the sample* (e.g., psychiatric outpatients, community residents, college students) as well as *% of sample that had current cannabis use disorder (CUD)*; (2) the *number of participants* in each study (N); (3) the *% of each sample that identified as female*; (4) the *mean age* of the sample; (5) the *duration of the EMA study in days*; (6) the *number of EMA assessment per day*; (7) the *compliance rate for prompted or scheduled assessments*; (8) the *nature of the event-contingent assessments if used* (e.g., about to use cannabis); (9) the *measure of cannabis use* (e.g., any, number of joints, number of puffs); (10) the *measure of mood or affect* used in the study; and (11) the *level of analysis* (e.g., momentary-, day-, person-level).

3. Results

We organize results from these studies by considering NA and PA separately. Within each affect section, we summarize findings according to sample composition (*community* or *clinical),* given the possibility of different affect-cannabis relations depending on the prominence of emotional dysregulation. Lastly, within each affect-sample section, we organize findings according to the level of analysis (momentary, day, and person).

Note that several studies report NA as an aggregate of more specific negative affective states such as sadness and anger, other studies report a combination of aggregated NA and specific negative affective states, and still, other studies report specific negative affective states without reporting aggregated NA. Of the studies that report specific negative affective states, most focus on anxiety, sadness/depression, and anger/hostility. Thus, in our review, we will include findings regarding these states as well as general NA. Some studies of clinical samples report relevant momentary psychopathology symptom measures as well, such as the Hamilton Anxiety Scale (Hamilton, 1959) or symptoms of psychosis such as paranoia. We report these findings when the symptoms are of depression or anxiety. The reporting of PA is more consistent: all studies (except one) report PA either as an aggregate of more specific positive affective states or as one specific state representing PA (e.g., happy). We specify the positive affective states assessed in the one study that does not follow this trend.

For studies that included multiple assessments per day, day-level predictors are usually reported as an average of that day's momentary scores; however, day-level predictors in studies that only included one assessment per day are indicative of that one score only (see Table 1 for a number of assessments per day). Any studies that report day-level analyses differently are noted in the text. Although person-level variables refer to the average score across all assessment occasions in the study, some researchers include variables measured at baseline as moderators in their analyses. Any such variables not based on aggregated EMA reports that are relevant to the current review are described in terms of how they were measured (e.g., diagnostic status, measured at baseline).

Table 2 presents a summary of results in terms of whether or not findings support hypotheses organized by sample type, level of analysis, type of affect, and temporal relation to cannabis use.

3.1. Negative Affect

3.1.1. Community Samples

3.1.1.1. Momentary Level.: Findings regarding the hypothesis of elevated NA prior to cannabis use are mixed. Buckner et al. (2015) and Buckner et al. (2013) found elevated NA prior to use, and Buckner et al. (2012a) found elevated anxiety prior to use. However, Chakroun et al. (2010) found that momentarily depressed mood was negatively associated with subsequent use, and found no association between anxiety and subsequent use. In addition, Tournier et al. (2003) found that anxiety was not associated with subsequent use. Although results from the Buckner et al. papers are from three separate studies, the studies used a similar methodology, potentially contributing to the consistency of those results. In particular, inspection of Table 1 reveals that all three studies measured cannabis use in terms of whether participants were *about* to use cannabis as opposed to whether participants had used cannabis since the last prompt. It seems possible that measuring NA immediately prior to cannabis use in this way may capture something systematically different than measuring NA at the previous prompt.

The three studies that examined NA following use are mixed as well, with one study showing decreased NA after cannabis use (Buckner et al., 2015), one study found no relation

between cannabis use and subsequent anxiety (Buckner et al., 2012a), and one study showing increased anxiety after use (Tournier et al., 2003).

3.1.1.2. Day Level.: Two studies reported negative associations between day-level anxiety and cannabis use (Buckner et al., 2012a; Hughes et al., 2014), while another showed increased ratings of own and others' interpersonal hostility on days of cannabis use (Ansell et al., 2015). However, given the lack of temporal precedence at this level of analysis, it cannot be determined whether these findings support the hypothesis. Additional studies examining day-level associations between cannabis use and NA showed null findings (Buckner et al., 2015; Hughes et al., 2014; Lex et al., 1989).

3.1.1.3. Person Level.: Two studies demonstrated positive associations between person-level anxiety and cannabis use. In particular, having an anxiety disorder was associated with a higher likelihood of cannabis use during the EMA period (Tournier et al., 2003), and having more than one anxiety disorder was associated with higher likelihoods of using cannabis. Similarly, Buckner et al. (2011) and, from the same study, Buckner et al. (2012b) found that momentary cannabis use was more likely during or following reports of craving if individuals scored higher at baseline on certain facets of trait-level anxiety sensitivity, and that momentary cannabis craving was positively associated with subsequent use for individuals with higher trait-level social anxiety.

Evidence regarding anger/hostility at this level was mixed. Lex et al. (1989) found a positive association between anger and cannabis use; individuals that used more cannabis during the EMA portion of their study had higher person-level ratings of anger. However, Ansell et al. (2015) found no association between person-level cannabis use and ratings of self and others' interpersonal hostility.

Lastly, Lex et al. (1989) found no difference in depression ratings between individuals who used cannabis more heavily and those who used cannabis less frequently.

There is some support for the hypothesis that higher person-level NA is associated with cannabis use, but this support is most consistent for anxiety, and it relies on individual-difference measures of anxiety assessed at baseline rather than the aggregation of EMA reports over time.

3.1.2. Clinical Samples

3.1.2.1. Momentary Level

3.1.2.1.1. General NA.: In a sample of young adults[1] recruited from outpatient medical clinics, Shrier et al. (2014) reported elevated NA at prompts just prior to cannabis use compared with NA more distant from use. In a sample of individuals with borderline personality or depressive disorders, cannabis use was positively associated with concurrent NA, even when adjusting for impulsivity and alcohol use; however, use was not associated

[1]The majority of this sample qualified as having poorer mental health measured by self-reported affect, depressive symptoms, state and trait anxiety, and social anxiety at baseline (Shrier et al., 2014). Therefore, though a psychiatric diagnosis was not required for inclusion in their study, we consider this a clinical sample.

with subsequent NA (Trull et al., 2016). In a sample of individuals with bipolar disorder who were euthymic during the study, NA was not related to subsequent cannabis use (Tyler et al., 2015). Two analyses of a data set from a sample of individuals who used cannabis and also had bipolar disorder (MJBP) showed lower total mood disturbance (TMD), an aggregate of tension, depression, anger, fatigue, and confusion subscale scores minus the subscale score for vigor on the Profile of Mood States (McNair et al., 1992), after using cannabis than prior to use (Gruber et al., 2012; Sagar et al., 2016). In addition, the MJBP group had higher TMD prior to use than the average TMD of healthy control (HC) participants, but after use, MJBP individuals no longer had significantly different TMD than HC individuals (Sagar et al., 2016). Henquet et al. (2010) found no association between cannabis use and prior or subsequent NA in their total sample of individuals with psychotic disorders and healthy controls, but individuals in the psychosis group had decreased NA following use. Lastly, in an extended version of this sample, Kuepper et al. (2013) found that momentary cannabis craving predicted use and that NA was positively associated with craving.

In sum, momentary associations between general NA and cannabis use for clinical samples largely support the hypothesis that NA would be elevated prior to use and decreased after use, with the majority of null findings being potentially attributable to the inclusion of participants that may be better characterized as community individuals (e.g., healthy controls in the study by Henquet and colleagues, 2010; individuals with bipolar disorder who were euthymic during the study by Tyler and colleagues, 2015).

3.1.2.1.2. Anxiety.: Gruber et al. (2012) reported improvement in anxiety symptoms after using cannabis for MJBP individuals. This momentary decrease in the MJBP group was also lower than the mean ratings of anxiety symptoms in the BP group even though the MJBP group's pre-use anxiety symptoms were (non-significantly) higher than the mean level of anxiety symptoms in the BP group. However, in the extended version of this sample, the MJBP group's pre-use anxiety symptoms remained higher than that of HC individuals after cannabis use (Sagar et al., 2016). For individuals with schizophrenia or schizoaffective disorder, Swendsen et al. (2011) found no association between cannabis use and subsequent anxious mood, and no association between anxious affect and subsequent cannabis use when instances of polysubstance use were removed from the models (Swendsen et al., 2011). Lastly, Trull et al. (2016) found no association between cannabis use and concurrent or subsequent anxiety. Thus, findings regarding anxiety at this level of analysis for clinical samples are mixed, with some evidence for an association between anxiety and subsequent use, but some null findings as well.

3.1.2.1.3. Sadness/Depression.: Similar to those for anxiety, findings regarding momentary associations between sadness/depression and cannabis use in clinical samples are mixed. Despite MJBP individuals showing improvements in depressed mood and depressive symptoms after cannabis use, their post-use levels remained higher than the mean levels of depressed mood and depressive symptoms of individuals in the BP and HC groups (Gruber et al., 2012; Sagar et al., 2016). Tyler et al. (2015) found that cannabis use was actually related to subsequent increases in depressive symptoms even with alcohol in the model for their sample of bipolar individuals who were euthymic at the time of the study,

and Trull et al. (2016) found that cannabis use positively predicted concurrent sadness even with alcohol use in the model. Lastly, Swendsen et al. (2011) found that cannabis use was less likely after high levels of sadness (even when instances of polysubstance use were removed from the models), and found no association between cannabis use and later sadness.

3.1.2.1.4. Anger/Hostility.: Findings for momentary relations between anger/hostility and cannabis use in clinical samples are more consistent, suggesting that cannabis use may lead to subsequent decreases in anger/hostility. Trull et al. (2016) found that momentary cannabis use was positively associated with concurrent hostility and that cannabis use predicted subsequently decreased hostility, even with alcohol use in the model. Similarly, Gruber et al. (2012) found decreased anger in the MJBP group after cannabis use. Further, MJBP individuals had higher anger prior to cannabis use compared with the mean level of anger in the BP group, but after use, MJBP group anger was no longer significantly different than the mean anger ratings of the BP group (Gruber et al., 2012). Similar results were found in the extended sample, showing that MJBP participants reported higher anger prior to cannabis use compared with the mean anger ratings of HC participants, but that after use, MJBP anger was no longer significantly different than HC participants' mean (Sagar et al., 2016).

3.1.2.2. Day Level.: Evidence regarding day-level associations between cannabis use and NA in clinical samples is mixed. Shrier et al. (2014) examined affective states in the 24-hour blocks of time preceding cannabis use and found higher NA in the 24 hours preceding use compared with more distal blocks of time. Using this same analytical method in clinically depressed outpatients, Bhushan et al. (2013) found no mean differences in NA in the 24 hours preceding use. Lastly, Trull et al. (2016) found that day-level cannabis use predicted increased NA, sadness, anxiety, and hostility at the moment, even after adjusting for alcohol use in the model. However, this analysis does not distinguish whether cannabis was used before, during, or after the increased levels of NA.

3.1.2.3. Person Level.: Trull et al. (2016) found that person-level cannabis uses positively predicted hostility in the moment, but was not associated with NA, sadness, or anxiety. This finding supports the hypothesis that person-level NA would be positively associated with cannabis use in terms of hostility specifically. However, use was not related to the other types of NA, and only one study examined these associations.

3.2. Positive affect

3.2.1. Community Samples

3.2.1.1. Momentary Level.: Buckner et al. (2015) found in the momentary level that participants reported higher PA in the event-contingent surveys that they completed when they were about to use cannabis; however, PA reported during random prompts was not related to cannabis use at the next prompt, and cannabis use had no effect on subsequent PA. Consistent with the first finding, Chakroun et al. (2010) found that PA was positively associated with subsequent cannabis use. Lastly, in a sample of community individuals who used cannabis and endorsed a desire to quit, Buckner et al. (2013) found that PA was not related to concurrent cannabis use when NA was included as a predictor. These findings

suggest that momentarily elevated PA precedes cannabis use in community samples, as the null finding by Buckner et al. was for individuals who were trying to quit using cannabis. However, there was no support for the hypothesis that PA would be increased during and after cannabis use.

3.2.1.2. Day Level.: Lex et al. (1989) found elevated friendliness, vigor, and elation on days where both cannabis and alcohol were used. These effects remained significant when all predictors were included in the models, except that using both cannabis and alcohol on the same day no longer predicted elevated elation. Buckner et al. (2015) found higher PA on days of cannabis use than non-use. These results are consistent with the hypothesis that PA would be elevated during cannabis use at the day level.

3.2.1.3. Person Level.: Lex et al. (1989) found that individuals who used cannabis more heavily during the EMA period reported lower friendliness, elation, and vigor on average than those who used less frequently.

3.2.2. Clinical Samples

3.2.2.1. Momentary Level.: Three analyses in two distinct studies reported no associations between PA and subsequent cannabis use (Henquet et al., 2010; Kuepper et al., 2013; Shrier et al., 2014). Similarly, Trull et al. (2016) found no relations between use and current or subsequent PA. However, Tyler et al. (2015) found that elevated momentary PA predicted cannabis use at the next prompt and that cannabis use was also related to subsequent increases in PA, even when alcohol use was included as a predictor in the model. In addition, Henquet et al. found elevated PA following cannabis use. These findings support the hypothesis that PA would be elevated after cannabis use; however, this is based on the findings from only two studies. Further, it is important to note again that the sample of Tyler and colleagues consisted of individuals with bipolar disorder who were euthymic at the time of the study, and may be more similar to community individuals.

3.2.2.2. Day Level.: Two studies found no differences in PA in the 24 hours preceding cannabis use (Shrier et al., 2014; Bhushan et al., 2013), and another reported no relation between day-level cannabis use and PA when alcohol use was included as a predictor in the model (Trull et al., 2016).

3.2.2.3. Person Level.: Trull et al. (2016) found no relation between person-level cannabis use and PA when alcohol use was included as a predictor in the model.

4. Discussion

Our review of the 19 articles that describe EMA studies examining the relations between cannabis use and affect revealed a few consistent findings. First, for clinical samples, momentary general NA seems to be elevated before cannabis use and reduced following use. Second, also for clinical samples, anger/hostility appears to be positively associated with concurrent cannabis use at both the day and momentary levels, and a few studies indicated momentary reductions in anger/hostility following cannabis use. Findings for sadness/

depression, anxiety, and PA in clinical samples were mixed, as were findings for community samples in general.

As indicated, the findings from our review are most consistent with the negative reinforcement theory of cannabis use. Notably, however, support for this model was found most consistently for general NA and anger/hostility (in the momentary level), but not for other types of NA such as anxiety or sadness/depression. Furthermore, support for this model was found for clinical samples but not for community samples. Lastly, contrary to our hypotheses, cannabis use was not consistently associated with PA. Recent evidence, however, suggests that PA may increase following use for individuals with cannabis dependence (Ross et al., 2018). Related, given the increases in negative emotional states due to decreases in the function of the dopamine component of the reward system typically present in individuals who use cannabis chronically or are dependent (Koob and Volkow, 2010), accounting for level of drug exposure is critical in understanding the relationship between cannabis use and affect. A limitation of the current review is that not all studies reported whether samples were comprised of individuals with CUD and, therefore, firm conclusions cannot be made about whether findings are different for those with CUD and those without. However, in the five studies that reported momentary findings for community samples, a more consistent pattern emerged regarding NA and cannabis use when CUD was considered. Specifically, findings from the three studies with the majority of participants meeting criteria for CUD supported the hypothesis of NA being elevated before cannabis use and lower after use (Buckner et al., 2012a; Buckner et al., 2015; Buckner et al., 2013), while the two studies with more participants not meeting criteria for CUD reported findings that did not support this hypothesis (Chakroun et al., 2010; Tournier et al., 2003). It is important to note, however, that the studies by Buckner et al. measured NA just prior to cannabis use during prompts where participants indicated that they were *about* to use cannabis, which may also contribute to the consistency of these results. Regardless, through this lens, these findings are consistent with the theory that negative reinforcement effects are more relevant for individuals who are further along in the progression to dependence than for individuals with less repeated drug exposure who use cannabis recreationally or occasionally (Koob and Volkow, 2010; Robinson and Berridge, 2003).

4.1. Limitations, Design Considerations, and Recommendations

A review of Table 1 reveals heterogeneity in the methodology of the studies included. Methodological and sampling differences likely contribute to the lack of consistency in associations between affect and cannabis use. Therefore, we present an overview of some limitations and caveats of existing EMA studies and offer recommendations for future EMA research in this area. These recommendations may improve the ability to test the tenets of the theories of affect and cannabis use as well as facilitate comparisons across studies. See Table 3 for a summary of these recommendations.

As with any study, it is important to consider, beforehand, the targeted sample to ensure results are generalizable to the population of interest. For example, a limitation of the current review is in our distinction between community and clinical samples. Specifically, we considered community samples to be any study that sampled individuals from the

community as opposed to psychiatric outpatient clinics or individuals endorsing clinical levels of psychopathology. However, not all studies of community samples *excluded* individuals on the basis of psychopathology. Therefore, despite not being comprised of individuals with psychopathology as a whole, community samples may still include some individuals with clinically relevant symptoms. In addition, individuals currently attempting to stop or reduce cannabis use (e.g., those currently in treatment for cannabis dependence) likely will show different cannabis-affect associations and have different expectancies about outcomes of stopping cannabis use than those who are not currently trying to cut down on their use. For example, non-treatment seeking individuals who use marijuana regularly anticipate worsening of mood states as a consequence of the cessation of cannabis use (Metrik et al., 2017). Perhaps those motivated to change their use and/or in treatment for CUD would be more likely to report NA prior to use (e.g., anxiety) or after use (e.g., guilt) than those who are not trying to quit. Alternatively, individuals with CUD might experience a greater reduction in momentary NA relative to individuals without CUD.

Furthermore, it is likely that cannabis use-affect associations depend on the amount and type of cannabis used (a point we return to below), number of years of exposure to cannabis and age of onset of use, current age of participants (e.g., adolescents, young adults, adults), gender of the participants, expectancies about the effects of cannabis, or cannabis use motives, all of which may influence the valence and intensity of reported subjective effects. Table 1 reveals a wide range of ages, gender representation, and sample compositions (e.g., trying to quit, community participants, or psychiatric outpatients). At the very least, investigators should be explicit about the nature of their samples, providing context for interpreting their findings (e.g., see Applebaum et al. 2018).

Another important consideration is the length of time in the study (e.g., number of days) as well as a number of assessments per day and types of assessments. As evident in Table 1, the length of the EMA studies we reviewed ranged from 6 days to 3 months. The choice of study length should be made based on the expected number of events of interest (in this case, cannabis use events), which will likely depend on the selection criteria of the sample. For example, if the EMA study is limited to only 7-days, one might only recruit individuals who use cannabis daily to ensure enough use to assess cannabis use-affect relations reliably. Longer studies (e.g., 4-weeks) can accommodate samples with less frequent use (e.g., twice per week).

Furthermore, in order to elucidate the temporal ordering of cannabis use and affective state we recommend using a combination of random and event-based prompts (initiated by the participant during cannabis use). In this way, mood when cannabis is not being used (e.g., at random prompts) can be used to estimate the change in affect when cannabis is being used. Random prompts can also “catch” cannabis use (by including an item assessing this) that has not been indicated by a user-initiated assessment. In addition, random prompts that occur after a cannabis use episode can help estimate longer-term effects on the affective state.

One of the most glaring limitations of previous studies (including our own; Trull et al., 2016) is the way cannabis use is quantified. At a most basic level, researchers may choose to assess whether cannabis was used (Yes/No). Table 1 indicates that many studies used this

simple dichotomous index for cannabis use, sometimes supplemented with a query concerning a number of “hits, joints, or bowls” used. Although straightforward, this approach is quite limited because it assumes that all use occasions or episodes and all cannabis strains are equal in terms of their effects on mood or other symptoms. For example, as previously mentioned, levels of THC in cannabis can vary dramatically (Mehmedic et al., 2010; Volkow et al., 2017), as can levels of CBD. There is also evidence that CBD may lessen the aversive effects of high THC concentrations (Fusar-Poli et al., 2009; Niesink, and van Laar, 2013). In other words, the observed increases in depression and anxiety with higher concentrations of THC might be mitigated by CBD, depending on its concentration. Therefore, it is important to characterize the strain (in terms of THC and CBD composition) in addition to the quantity of cannabis used (in grams). If strain characterization is not feasible, it would be beneficial to include momentary questions regarding amount used compared to usual for a person as well as the perceived potency of the cannabis used.

It is also important to note that all modes of cannabis use are not equal in terms of the timing of effects. Smoked cannabis (the most common mode of administration) produces immediate psychoactive effects, with peak intoxication at 30-minutes from the start of smoking (Grotenhermen, 2003). However, the onset of psychoactive effects from cannabis administered orally is substantially delayed. If not accounted for in the design or analyses of the study, this could confound the results and interpretations of acute mood effects after ingestion.

Cannabis is, at times, used with other substances, especially alcohol (Yurasek et al., 2017). For example, NESARC data indicate that over 80% of those with a lifetime DSM-IV diagnosis of cannabis abuse or dependence also met criteria for a lifetime diagnosis of alcohol abuse or dependence (Buckner et al., 2012c). Cannabis use in the past year was also associated with more than double the risk of a diagnosis of alcohol use disorder approximately 3-years later (Blanco et al., 2016; Weinberger et al., 2016). The co-use of cannabis and alcohol results in more impaired driving than the use of either substance alone (Hartman and Huestis, 2013). Furthermore, alcohol may increase the body’s absorption of THC (Lukas and Orozco, 2001) and potentiate cannabis intoxication (Hughes et al., 2014). There is also preliminary laboratory evidence that working memory is negatively affected by the co-use of alcohol and cannabis more than that found when these substances were used alone (Winward et al., 2014).

In addition, the co-exposure to cannabis and nicotine is common (Agrawal et al., 2012). Not only are cannabis and nicotine sometimes co-used via separate intake methods, but they may also both be present in the same vehicle for use, such as in spliffs that contain both tobacco and cannabis (Schauer et al., 2017). Nicotine use can be conceptualized from both a positive and negative reinforcement perspective (George and Koob, 2017; Piasecki et al., 2016). Early use of nicotine is often associated with PA, while those who are dependent on nicotine experience NA during withdrawal. Currently, little is known about the affective states preceding, during, and following co-use of cannabis and nicotine in daily life.

Few studies we reviewed considered the use of other substances (e.g., alcohol, nicotine). Therefore, we recommend that future EMA studies of cannabis use also assess the use of

alcohol and other drugs. Effects of cannabis alone may differ, perhaps dramatically, from the combined effects of cannabis and alcohol and/or nicotine. By assessing co-use of cannabis and other substances, it is possible to isolate effects on the affect of cannabis alone, other substances alone, and co-use of cannabis and other substances (Trull et al., 2016). In addition to assessing the use of other substances in daily life, it is important to characterize the stage of use (e.g., early stages versus dependent) to better understand any stage-dependent mood effects that are relevant for cannabis, alcohol, and nicotine. Finally, the co-use of substances should be considered in the context of the sample population. For example, college students may experience different associations between affect and co-use of cannabis and alcohol than adults using both substances simultaneously.

Another potential influence on the subjective effects of cannabis is that of outcome expectancies about the drug's positive and negative effects (Metrik and Rohsenow, 2013) as well as motivations for use (e.g., Ross et al., 2018). For example, cannabis smoking reliably increases heart rate with peak elevations occurring 10–15 minutes following smoking (Hart et al., 2001), and expectancies regarding the effects of smoking ("euphoria" versus "makes me paranoid or anxious") may influence the interpretation of this physiological effect. Interestingly, only a few studies have examined the influence of expectancies on subjective reports of affect after smoking cannabis. For example, Metrik et al. (2011) found that individuals that endorsed expectancies for more impairment on their thoughts and behavior reported higher levels of anxiety after smoking cannabis. In contrast, those with more salient tension reduction expectancies were more likely to report feeling better after smoking cannabis. Metrik et al. (2011) concluded that tension reduction expectancies appear to be more directly related to increases in PA after smoking cannabis while impairment expectancies were more closely tied to NA following use. Motives for use may also moderate relations between cannabis use and affect. For example, in a subsequent analysis of data from Shrier et al. (2012), Ross et al. (2018) found that individuals who reported using cannabis to cope with NA had higher NA scores within an hour of use, but NA subsequently decreased over time (3–12 hours after use). These findings suggest that EMA studies examining cannabis-affect relations should include measures of cannabis expectancies or motives either at baseline or imbedded in the study at the *momentary level* to better understand cannabis-affect relations during daily life.

An additional limitation of the reviewed studies involves sample size. Few of the reviewed studies included more than 50 participants. The collection of EMA data several times per day, over multiple days, results in a potentially large number of assessments per individual, improving statistical power for both momentary- and day-level analyses. However, power may still be an issue for person-level level analyses as well as modeled interactions involving person-level covariates (e.g., gender, groups, person-level scores, etc.). Specifically, samples of 50 or less are unlikely to be able to detect small effects at the person-level. If the goal of the study is to assess the influence of predictors at the person-level as well, then more participants need to be sampled to have the statistical power to assess small effects as well. This, in fact, may be responsible for some of the null and mixed findings for person-level effects in the present review.

Finally, the lack of consistency in how affective states were measured is another notable limitation of the reviewed studies. The variability in measuring affective states presents challenges for both replication and generalizability. As shown in Table 1, few studies used the same measures for affect. Many studies used single-item measures (SUDs scales), which may be less reliable, or investigators selected a subset of items from existing measures. In addition, many studies assessed general NA as an aggregate of more specific negative affective states without examining potential differences based on the type of NA. Given some differential effects for different types of NA, specific states such as hostility, anxiety, or sadness should be examined as well. More consistency of measurement of affective states is needed in the future to confidently conclude that findings are replicated across studies.

5. Conclusions

Our review of existing EMA studies examining the relations between cannabis use and affect revealed the most consistent associations between both general NA and anger/hostility and cannabis use. These findings offer support for the negative reinforcement model of cannabis use. However, findings for other specific negative affective states and PA were mixed. We recommend future EMA studies of affect and cannabis use consider sample composition, study length, sampling strategy, quantification of cannabis use, and concurrent use of other substances (especially alcohol) when designing the study and analyzing the EMA data.

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Highlights

- We reviewed studies of the relations between cannabis use and affect in daily life.
- Cannabis use may relieve negative affect and anger/hostility in clinical samples.
- Findings for other affects in clinical samples and for community samples are mixed.
- Cannabis use disorder may influence momentary associations for community samples.
- Well-characterized samples will enhance the future integration of findings.

Table 1.

Design details of reviewed studies.

Reference	Sample; % with current CUD	N	% Female	Mean Age (SD)	Duration	Number of scheduled assessments per day	% Compliance	Event-contingent assessments	Cannabis measure	Momentary mood measure	Level of analysis (M=momentary, D=day, P=person)
Ansell, Laws, Roche, and Sinha, 2015	Community (recruited for a drinking study); 0%	43	60.5	23.7 (4.6)	14 days	1	96	Substance use; interpersonal interactions lasting longer than 5 minutes	Number of hits and method of intake, but analyzed as yes/no	"Rate how the *other person* acted during the interaction" and "Rate how *you* acted during the interaction" on a scale from distant to friendly	D, P
Bhushan, Blood, and Shrier, 2013	Clinically depressed outpatients; N/A	38	84	18.2 (1.9)	14 days	4-6	unknown	Substance use	Yes/no	Abbreviated Positive and Negative Affect Schedule (PANAS)	D
Buckner, Crosby, Silgado, Wonderlich, and Schmidt, 2012a	College students; 63%	49	38.8	19.14 (1.02)	14 days	7	62	About to use cannabis	About to use cannabis: yes/no	Subjective Units of Distress (0-10)	M, D
Buckner, Crosby, Wonderlich, and Schmidt, 2012b	College students; 63%	49	38.8	19.14 (1.02)	14 days	7	62	About to use cannabis	About to use cannabis: yes/no	Subjective Units of Distress (0-10)	M, D, P
Buckner et al., 2015	Community; 87.1%	93	34.4	20.95 (2.62)	14 days	7	67.6	About to use cannabis	About to use cannabis: yes/no	PANAS (20-item)	M, D
Buckner, Zvolensky, and Ecker, 2013	Community people who endorsed a desire to quit using cannabis; 83.3%	30	33.3	22.13 (5.96)	14 days	7	64.5	About to use cannabis	About to use cannabis: yes/no	PANAS (20-item)	M
Buckner et al., 2011	College students; 63%	49	38.8	19.14 (1.02)	14 days	7	62	About to use cannabis	About to use cannabis: yes/no	Subjective Units of Distress (0-10)	M
Chakroun, Johnson, and Swendsen, 2010	College students; 25% (of the group of cannabis users)	212	64	19.5 (1.1)	7 days	5	63.1	None	Yes/no use since last prompt, and "number of marijuana cigarettes"	Depressed, anxious, happy	M
Gruber et al., 2012	Patients with bipolar disorder who use cannabis (MJBP), healthy controls who use cannabis (MJ), and patients with bipolar disorder who do not use cannabis (BP); 100% (of MJBP and MJ group), 0% (of BP group)	MJBP: 12, MJ: 20, BP: 11	N/A	MJBP: 24.25 (4.29); MJ: 20.75 (2.67); BP: 29.45 (7.10)	4 weeks	3	unknown	Cannabis use	Amount (grams), frequency, mode of use	Hamilton Anxiety Scale, Montgomery-Asberg Depression Rating Scale, Profile of Mood States	M
Henquet et al., 2010	Patients with psychotic disorder and healthy controls; N/A	Patients: 42, Controls: 38	Patients: 26.2, Controls: 18.4	Patients: 36.1 (9.3), Controls: 26.9 (7.5)	6 days	12	unknown	None	Yes/no	PA: Cheerful, relaxed, happy, satisfied, enthusiastic, overall good; NA: insecure, lonely, anxious, blue, guilty	M, P

Reference	Sample; % with current CUD	N	% Female	Mean Age (SD)	Duration	Number of scheduled assessments per day	% Compliance	Event-contingent assessments	Cannabis measure	Momentary mood measure	Level of analysis (M=momentary, D=day, P=person)
Hughes et al., 2014	Community people who endorsed a desire to quit or reduce using cannabis; 74	142	58	33 (N/A)	3 months	1	92	None	Total times per day; number of joints, pipes, or bowls, method of intake	Anger, anxiety, sadness	D
Kuepper et al., 2013	Patients with non-affective psychotic disorder and healthy controls; N/A	Patients: 40, Controls: 57	Patients: 40.0, Controls: 28.1	Patients: 37.7 (9.15), Controls: 27.4 (9.16)	6 days	12	unknown	None	Yes/no	PA: Cheerful, relaxed, happy, satisfied, overall well; NA: insecure, lonely, anxious, down, irritated, guilty	M
Lex, Griffin, Mello, and Mendelson, 1989	Community; N/A	30	100	26.4 (4.4)	3 months	1	99.1	None	Number of marijuana cigarettes or compounds smoked that day	Profile of Mood States	D, P
Sagar et al., 2016	Patients with bipolar disorder who use cannabis (MJBP), healthy controls who use cannabis (MJ), patients with bipolar disorder who do not use cannabis (BP), and healthy controls (HC); 0% (of BP and HC groups), N/A (for MJBP and MJ groups)	MJBP: 12, MJ: 23, BP: 18, HC: 21	N/A	MJBP: 24.25 (4.29); MJ: 20.75 (2.67); BP: 29.45 (7.10)	4 weeks	3	unknown	Cannabis use	Amount (grams), frequency, mode of use	Hamilton Anxiety Scale, Montgomery-Asberg Depression Rating Scale, Profile of Mood States	M
Shrier, Ross, and Blood, 2014	Medical outpatients; 64% (met for DSM-IV dependence, abuse not reported)	40	58	18.7 (2.1)	14 days	4-6	70.9	Before and after cannabis use	Yes/no	Abbreviated PANAS (12-item)	M, D
Swendsen, Ben-Zeev, and Granholm, 2011	Patients with schizophrenia or schizoaffective disorder; N/A	Schizophrenia: 144, Schizoaffective disorder: 55	39.3	46.5 (11.2)	7 days	4	72.1	None	Yes/no	Sad mood, anxious mood	M
Tournier, Sorbara, Gindre, Swendsen, and Verdoux, 2003	College students; 39.2%	79	69.6	22.1 (5.3)	7 days	5	91.6	None	Yes/no	Anxiety	M, P
Trull, Wycoff, Lane, Carpenter, and Brown, 2016	Patients with borderline personality disorder (BPD) or depressive disorders (DD); N/A	BPD: 60, DD: 33	85	30.9 (11.2)	28 days	6	90.5	None	Yes/no	PANAS (27-item)	M, D, P
Tyler, Jones, Black, Carter, and Barrowclough, 2015	Patients with bipolar I or bipolar II disorder; 62.5%	24	33.3	37.1 (12.6)	6 days	10	unknown	None	Yes/no	PA: Cheerful, excited, relaxed, satisfied, happy; NA: lonely, anxious, irritated, sad, guilty; Depression symptoms: slowed down, low, bad about myself, and fearful	M

Table 2.

Overview of results by level of analysis, affect, and temporal order for each hypothesis.

	Results									
	Momentary level					Day level				Person level
	NA		PA			NA		PA		NA
Reference	Before use	After use	During use	After use		Before use	After use	During use	After use	
Community samples										
Ansell, Laws, Roche, and Sinha, 2015							null (hostility)			null (hostility)
Buckner, Crosby, Silgado, Wonderlich, and Schmidt, 2012a (same study as Buckner et al., 2012b, 2011)	+ (anxiety)	null (anxiety)								
Buckner, Crosby, Wonderlich, and Schmidt, 2012b (same study as Buckner et al., 2012a, 2011)										null(anxiety)
Buckner et al., 2015	+ (general NA)	+ (general NA)		null				+		
Buckner, Zvolensky, and Ecker, 2013	+ (general NA)		null							
Buckner et al., 2011 (same study as Buckner et al., 2012a, 2012b)										+ (anxiety)
Chakroun, Johnson, and Swendsen, 2010	− (depression), null (anxiety)									
Hughes et al., 2014										
Lex, Griffin, Mello, and Mendelson, 1989								+		+ (anger), null (depression)
Tournier, Sorbara, Gindre, Swendsen, and Verdoux, 2003	null(anxiety)	− (anxiety)								+ (anxiety)
Clinical samples										
Bhushan, Blood, and Shrier, 2013						null (general NA)				
Gruber et al., 2012 (same study as Sagar et al., 2016)	+ (anger)	+ (general NA, anxiety, depression, anger)								

	Results										
	Momentary level					Day level					Person level
	NA		PA			NA		PA			NA
Reference	Before use	After use	During use	After use		Before use	After use	During use	After use		
Henquet et al., 2010 (same study as Kuepper et al., 2013)	null (general NA)	+ (general NA)		+							
Kuepper et al., 2013 (same study as Henquet et al., 2013)	+ (general NA)										
Sagar et al., 2016 (same study as Gruber et al., 2012)	+ (general NA, anger)	+ (general NA,depression, anger), null (anxiety)									
Shrier, Ross, and Blood, 2014	+ (general NA)					+ (general NA)					
Swendsen, Ben-Zeev, and Granholm, 2011	null (anxiety), − (sadness)	null (anxiety, sadness)									
Trull, Wycoff, Lane, Carpenter, and Brown, 2016		null (general NA, anxiety), + (hostility)	null					null			null (general NA, sadness, anxiety), + (hostility)
Tyler, Jones, Black, Carter, and Barrowclough, 2015	null (general NA)	− (depression)		+							

Note. + = supports hypothesis, − = opposite to hypothesis, null = neither supports nor offers opposite findings to hypothesis, blank = study did not report findings for that cell

Table 3.

Overview of design considerations and recommendations.

	Recommendations
Sample characteristics	• Sample size: smaller samples with many assessments can have adequate statistical power for momentary or day effects, but if interested in person-level effects, need a larger sample, especially to detect small effects
	• Consider clinical or community
	• If community, consider and report whether psychopathology excludes participation
	• Establish cannabis use disorder diagnosis, and severity, and consider this in analyses
	• Consider differences based on whether participants are in treatment for cannabis use or trying to cut down
	• Consider and report number of years of exposure to cannabis or age of onset
	• Assess baseline motives and expectancies of cannabis use
Procedures	• Length of time in the study and number of assessments per day will depend on frequency of use of participants
	• Recommend including both random and event-based prompts
Measures	• Quantify cannabis use more specifically than yes/no. For example, assess number of hits/joints/bowls; consider level of THC and CBD in product used; inquire in the moment about perceived potency; and account for mode of administration
	• Measure other substance use (e.g., alcohol, nicotine) and adjust for this in analyses
	• Measure momentary motives and expectancies of use
	• Consider specific types of negative affect (NA) in addition to general NA