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Substance use outcomes for mindfulness based relapse prevention are partially mediated by reductions in stress: Results from a randomized trial

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ABSTRACT

Objective: Mindfulness based relapse prevention (MBRP) has demonstrated efficacy in alleviating substance use, stress, and craving but how MBRP works for marginalized young adults has not been investigated. The current study used a novel rolling group format for MBRP as an additional intervention for young adults in residential treatment. We tested the hypothesis that MBRP (plus Treatment as usual (TAU)) would reduce stress, craving, and substance use among young adults in residential treatment relative to treatment-as-usual plus 12-step/self-help meetings (TAU only). Further, we examined whether reduced stress during treatment was a potential mechanism of change operating in MBRP.

Method: Seventy-nine young adults (M_{age} = 25.3, SD = 2.7; 35 % female) were randomly assigned to MBRP (n = 44) or TAU (n = 35). Follow-up assessments were conducted bi-monthly for self-reported measures of stress, craving, and substance use.

Results: At treatment completion young adults receiving MBRP had lower substance use (d = −0.58, [−0.91, −0.26]), craving (d = −0.58, [−1.0, −0.14]), and stress (d = −0.77 [−1.2, −0.30]) relative to TAU condition. Reduced stress during treatment partially mediated observed outcome differences between MBRP and TAU for substance use ($\beta_{indirect}$ = −0.45 [−0.79, −0.11]).

Conclusions: Results suggest that MBRP is a useful and appropriate intervention for marginalized young adults. Further, our results suggest that the effects of MBRP on long-term substance use outcomes may be partially explained by reduced stress.

1. Introduction

Substance use and stress are among the most detrimental contributors to psychological, behavioral and health-related problems (Andersen & Teicher, 2009). The risk for substance use is particularly pronounced in young adulthood (age 18–29; Sussman & Arnett, 2014), and compared to both adolescents (age 12–17) and adults (age 30 and above), young adults exhibit the highest rates of cannabis use (19%), alcohol use (59.6%), binge drinking (37.9%), and illicit drug use (21.5%) (SAMHSA, 2014). One explanation for why young adults are so susceptible to substance use is stress (Shonkoff & Garner, 2012; Shonkoff et al., 2009). From the psychological tradition, stress, in general, is defined as an individual's subjective appraisal of an event as threatening, or otherwise harmful, yet their ability to cope with the stressful event is inadequate or unavailable (Cohen, Gianaros, & Manuck, 2016). With stress being posited as one of the most consistent predictors of continued use of alcohol or drugs and relapse (Shonkoff & Garner, 2012; Sinha, 2001), young adults who have experienced abnormal amounts of stressful life events (e.g., childhood trauma, criminal justice involvement, foster care) are at a higher risk of developing substance use disorders and experiencing more substance related problems later in life (Ford, Grasso, Hawke, & Chapman, 2013). This may be particularly true for *marginalized* young adults, or individuals who have been (or are) involved in the child welfare system, criminal justice

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system, or have not attended some form of higher education (IOM, 2014). In particular, marginalized young adults, compared to their peers, are less likely to graduate from high school, have low rates of college attendance, more involvement in the criminal justice system, are more likely to be unemployed, and experience high levels of housing instability and homelessness (IOM, 2014). With marginalized young adults having a heightened risk for mental health, physical health, substance use problems (Scott & White, 2005; Traube, James, Zhang, & Landsverk, 2012) and worse substance use treatment outcomes (Davis, Smith, & Briley, 2017), research on effective interventions for marginalized young adults that address substance use and the factors that prompt relapse, such as stress, are urgently needed.

Studies of clinical populations have shown that clients entering substance use treatment report heightened levels of stress and an inability to adaptively cope with acute stressors (see Sinha, 2008 for a review). Several early studies show that stress is positively associated with abuse and relapse of opiates and psychostimulant drugs (Gawin, 1991; O'Doherty, 1991). Sinha (2001) found that cocaine users exposed to stress imagery had significantly higher cocaine cravings and increased physiological stress response. One treatment modality that has shown strong evidence in reducing both stress and substance use are mindfulness based interventions (Li, Howard, Garland, McGovern, & Lazar, 2017). For example, several studies have assessed mindfulness based interventions, namely mindfulness based substance abuse treatment for adolescents (MBSAT), with at-risk youth (Barnert, Himelstein, Herbert, Garcia-Romeu, & Chamberlain, 2014; Himelstein, Hastings, Shapiro, & Heery, 2012; Himelstein, Saul, & Garcia-Romeu, 2015). For example, Himelstein et al. (2015) found support for reductions in problem behaviors and improvements in decision making and self-esteem among justice involved youth following a 12 week MBSAT program. Other studies of MBSAT have found reductions in perceived stress and increases in self-regulation (Himelstein et al., 2012) as well as decreases in impulsivity and increased perceived risk or drug use (Himelstein, 2011) among incarcerated adolescents following an 8–10 week MBSAT program. Other mindfulness based interventions such as mindfulness based relapse prevention (MBRP), a particular form of mindfulness training designed for drug and alcohol use patients (Bowen et al., 2009; Witkiewitz, Marlatt, & Walker, 2005), has been shown to reduce perceived stress (Brewer, Bowen, Smith, Marlatt, & Potenza, 2010) and days of substance use (Bowen et al., 2009; Brewer, Elwafi, & Davis, 2013) among adults. MBRP was developed to target negative thought processes, such as rumination and craving, which play significant roles in relapse (Witkiewitz, Bowen, Douglas, & Hsu, 2013). Keeping in line with general practices of mindfulness interventions, MBRP aims to increase a patient's ability to tolerate problematic cognitive and physiological experiences by helping remain present focused through meditative practice (Bowen et al., 2009). Participants are taught to “respond” (versus react) to situations that may trigger use through present-moment focus rather than reacting in a habitual manner (Witkiewitz & Bowen, 2010). MBRP aids in identifying high risk situations while creating alternative responses and coping strategies to respond to triggers (Witkiewitz et al., 2013). Emerging evidence indicates that mindfulness based interventions (no specificity) may have powerful effects on overall substance use ($d = -0.33$), opiate use ($d = -0.51$), craving ($d = -0.65$), and stress ($d = -1.21$) (Li et al., 2017). However, prior research investigating the effects of MBRP have been mixed, with individual studies showing strong effects but a recent meta-analysis showing no differences between MBRP and comparison groups (Grant et al., 2017). An example of a study showing strong MBRP effects is that of Witkiewitz et al. (2014), who found at 15-week follow-up, adult women offenders assigned to MBRP showed significantly fewer days of drug and alcohol use ($d = 0.36$–0.45), and significantly fewer legal problems ($d = 1.18$) compared to individuals assigned to relapse prevention only. Further, Bowen et al. (2014) found that, compared to treatment as usual (TAU), adults in a step down residential treatment program assigned to MBRP showed a 54% decreased risk of relapse for drug use and a 59% decrease risk of relapse for heavy drinking.

Although these studies find mixed results for MBRP with adults, there remain two significant gaps in the literature. First, little is known regarding how MRBP works for young adults. In two recent meta-analyses on mindfulness interventions for substance misuse, only two studies focused on young adults, and these studies employed convenience samples of college students (Grant et al., 2017; Li et al., 2017). While these studies provide needed information on the effects of mindfulness on substance use, young adults in residential settings are a more severe population relative to the general college population and more studies are needed to evaluate the effectiveness of MBRP with this severe population. Further, the most stress prone young adults in substance use treatment tend to receive residential services (Sinha, 2008), and yet not a single randomized study on MBRP exists with this population (Grant et al., 2017). Second, of the studies investigating MBRP, few have assessed the role reductions in stress may play (e.g., mechanism) in long-term substance use and craving outcomes. One study found that those assigned to mindfulness training had significantly lower physiological and psychological stress reactivity following a stress provocation lab task (Brewer et al., 2009), but no differences existed between groups on substance use outcomes. Recently, Goldberg et al. (2014) showed hair cortisol concentration (chronic stress indicator) was associated with decreases in cigarette smoking behavior after mindfulness training, indicating that changes in stress may be a key player in understanding changes in other substance use behaviors. However, many of the reviewed studies did not utilize a high stress sample, and a lack of stress or failure to screen participants for high stress is a shortcoming of prior research. Nonetheless, to date, no study has investigated the relationship between receipt of MBRP, changes in perceived stress levels, and substance use outcomes (e.g., days of use and craving) among a sample of marginalized young adults. The current study will address these gaps and assess the effectiveness of MBRP with a high risk, high stress sample of young adults.

1.1. Study objectives and hypotheses

The primary objective of the study was to examine the effect of our experimental condition (treatment as usual + MBRP) compared a control condition (treatment-as-usual plus additional 12-step meetings (TAU)) on perceived stress, craving and substance use. We hypothesized participants who received MBRP would have lower craving during the *treatment phase* (e.g., from study entry to treatment discharge) and *post-treatment phase* (e.g., from discharge to 6-month follow-up) (H1), fewer substance using days during the post-treatment phase (H2), and lower perceived stress during the treatment phase and post-treatment phase (H3). Further, among those who received MBRP, reductions in treatment-phase stress would mediate the association between treatment assignment and post-treatment craving (H4) and substance using days (H5). Pre-registered hypotheses can be found in our open science framework portal here: https://osf.io/83x3t/ (Davis & Roberts, OSF, 28 June 2017).

2. Method

2.1. Procedures and participants

The study was approved by the University Institutional Review Board. Participants were recruited between September 2015 and November 2016, with follow-up assessments continuing until June 2016. Treatment status was concealed from research assistants conducting assessments, and the trial adhered to established procedures to maintain separation between research staff who conducted assessments and delivered the intervention. Treatment took place at a residential public not-for profit substance use treatment center that provided care to low income clients (18 years and older) with substance use disorders.

Participants were, on average, 25.3 (SD = 2.7) years old (see Table 1 for all baseline demographics). The majority of clients were White (91%), male (65%) and had less than a high school education (mean years of education was 11.9). Most participants had parents with a high school degree or less (Mother: 66%, Father: 83%) and parents who abuse alcohol or other drugs (Mother: 73%, Father: 88%). The majority (65%) of clients were unemployed or receiving some form of Social Security entitlements. The median yearly salary was $5500, with most spending a large proportion of time in jail or prison (Mean past 90 days in jail = 41.3) prior to entering the residential facility. Over 90% of participants were poly substance users (i.e., had multiple substance use disorder diagnoses) and all participants were diagnosed with a substance use disorder. The average length of stay at the treatment facility was 41 (SD = 26.2) days.

Table 1
Baseline demographic characteristics for MBRP and TAU.

	Total M (SD) or n (%)	MBRP M (SD) or n (%)	TAU M (SD) or n (%)	t-test	χ^2	p
Participant characteristics						
Days in residential	41.6 (26.3)	43.3 (35.1)	39.3 (30.7)	−0.67		.50
Age	25.3 (2.70)	25.3 (2.80)	25.3 (2.64)	0.04		.97
Female n (%)	28 (35.0)	17 (37.8)	11 (31.4)		0.35	.55
Race/ethnicity n (%)						
White	73 (91.3)	42 (93.3)	31 (88.6)		2.13	.35
African-American	6 (7.5)	2 (4.44)	4 (11.3)			
Native American	1 (1.25)	1 (2.22)				
Relationship						
Single	48 (60.0)	25 (55.6)	23 (65.7)		1.61	.66
Divorced	8 (10.0)	6 (13.3)	2 (5.71)			
Serious relationship	16 (20.0)	9 (20.0)	7 (20.0)			
Married	8 (10.0)	5 (11.1)	3 (8.57)			
Education & employment						
School n (%)						
Not in school	70 (87.5)	41 (91.1)	29 (82.9)		2.46	.29
Adult education[a]	3 (3.75)	2 (4.44)	1 (2.86)			
2 year college	7 (8.75)	2 (4.44)	5 (14.29)			
Last grade completed	11.9 (1.63)	11.9 (1.75)	11.9 (1.48)	−0.15		.88
Employment n (%)						
Full-time	23 (28.8)	14 (31.1)	9 (25.7)		1.74	.42
Part-time	5 (6.25)	4 (8.89)	1 (2.86)			
Unemployed	52 (65.0)	27 (60.0)	25 (71.43)			
Salary (median)	5500	6000	5000			
Salary (mean)	16,807 (36, 185)	18, 617 (31,337)	14, 479 (41, 971)	−0.51		.62
Substance use[b]						
SFS P90[c]	16.1 (9.99)	14.8 (9.29) 7.74 (8.63)	17.7 (10.7)	1.29 1.88		.21 .07
SFS P14	9.51 (9.73)		11.8 (10.7)			
Self-help/social support						
Num. self-help[d]	1.87 (3.78)	2.06 (3.47)	1.62 (4.19)	−0.51		.61
Craving						
Total craving score	4.65 (2.78)	4.31 (2.89)	5.08 (2.59)	1.24		.22
Perceives stress						
Total stress	33.7 (7.96)	34.9 (7.11)	32.2 (8.81)	−1.49		.14
Mindfulness						
Total mindfulness (MAAS)[e]	3.19 (0.781)	3.19 (0.689)	3.17 (0.894)	−0.07		.95
Practice mindfulness	5.76 (13.9)	3.96 (9.70)	8.09 (17.9)	1.32		.19

Note: MBRP = mindfulness based relapse prevention; TAU = Treatment as Usual (control condition). Items or measures followed by a P90 or P14 refer to past 90 days (P90) or past 2 weeks (P14). a. Adult education includes GED classes. b. Substance use was measured in two ways past 90 days (P90) and past two weeks (P14). c. SFS is a variable created to contain information on all substances and three substance problem items. The scale calculates the proportion of days each individual uses all 15 substances or experiences problems. These values are averaged and multiplied by 100. d. Participants were asked how many days they attend any 12-step, self-help, or other social support group in the past 2 weeks. e. Mindful Attention Awareness Scale (MAAS).

2.2. Recruitment and consenting

Eighty-four participants were screened during the facility's existing intake procedures and 79 were eligible for the study. Eligibility criteria included: a) residency at the treatment center, b) being aged 18 to 29, c) proficiency in the English language, and d) clear cognitive ability to understand and provide consent.

Once eligibility was determined, research staff discussed the study purpose, what role they would play, the difference between control and experimental groups, intake and follow-up procedures, and expectations during the 6-month study period. Research staff explained that individuals assigned to the experimental group would receive eight additional MBRP group sessions and those assigned to the control group would receive eight additional self-help/12-step facilitation groups. If participants agreed to enter the study, they completed an informed written consent prior to commencing the study. Both groups received treatment at the residential facility, which was a mixture of group cognitive behavioral therapy, self-help guidance, and individual therapy. Each participant was read and given a copy of the informed consent document. Next, all participants underwent an initial baseline assessment using the online platform Qualtrics LLC. This assessment took, on average, between 40 and 60 minutes to complete. Following the intake assessment participants were randomly assigned to MBRP (n = 44) or TAU (n = 35). Treatment allocation was performed randomly by an online "Clinical trial randomizer" (www.randomization.com) (Suresh, 2011). On average, participants attended their first MBRP session within two days of initial intake.

All participants, regardless of treatment assignment, were provided with bi-weekly follow-up assessments for 6 months. Thus, during the *treatment phase* participants were given assessments on 3 occasions (baseline, 2 weeks, 1 month) and during the post-treatment phase participants were given follow-up assessments on 12 occasions (assessment every 2 weeks), for a total of 15 possible time points. Completion times for follow-up assessments averaged 15–20 minutes. Participants received $10.00 ($150.00 maximum) for each assessment. We also provided two $150.00 bonus drawings during the follow-up period. A participant flow diagram is depicted in Fig. 1.

2.3. Attrition analysis

Attrition ranged from 0%–32% across follow-ups. Among participants, 17% (n = 14) did not have any data during the post-treatment phase. Further, 95% completed assessments during the 1-month period, 81% completed follow-up assessments during the 3-month period, and 75% completed follow-up assessments during the 5-month period. To assess potential differences between individuals lost to follow-up and those who completed the majority of follow-up assessments, attrition analyses were conducted on the main variables of interest. No differences were found between those lost to follow-up and those not lost to follow-up (see Supplementary materials for test statistics).

2.4. Analytic sample

All models were fitted using the full information maximum likelihood (FIML) estimator available in *Mplus* (Muthén & Muthén,

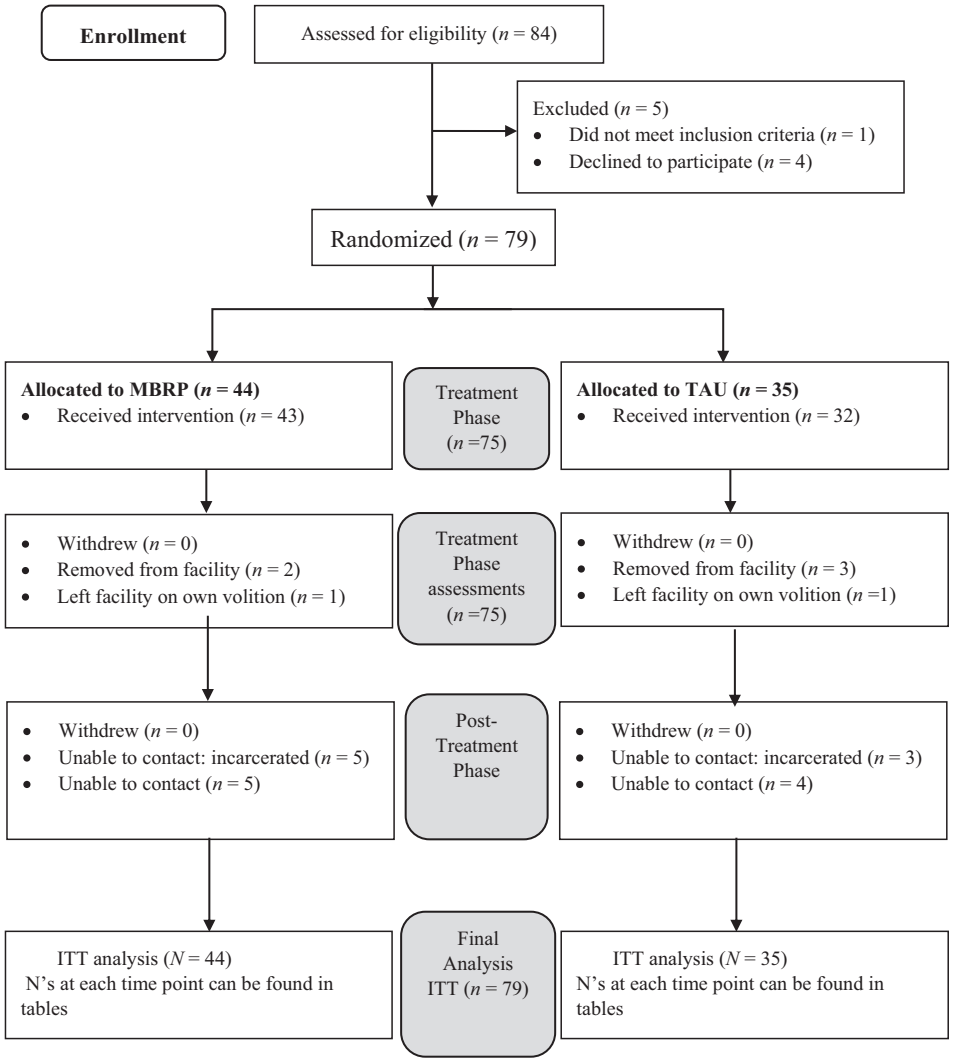

Fig. 1. Consolidated Standards of Reporting Trials (CONSORT) diagram. ITT = intent to treat; MBRP = mindfulness based relapse prevention; TAU = treatment as usual.

1998–2017), treating all observed predictors as single-item latent variables. As such, all individuals contribute all their available data (including those with missing time-invariant *X* variables). In so doing we, invoked the assumption that missing data were conditionally random, after adjusting for the other variables included in the likelihood function (i.e., missing at random; MAR). The plausibility of this assumption was strengthened by our inclusion of variables that likely serve of proxies for unobserved missingness mechanisms (e.g., days in treatment, days in jail/prison). Our final analytic sample was 79 participants.

2.5. Interventions

2.5.1. MBRP

The experimental group received treatment normally provided by the residential facility as well as eight 1.5-hour group sessions of MBRP (see Supplemental material for session details). Because the average residential stay is only one month, sessions were delivered twice weekly to ensure completion of all 8 sessions. One important difference in our delivery of MBRP compared to the standard version is the use of rolling groups (Witkiewitz et al., 2014). This allowed us to enroll individuals as they entered the residential facility, rather than employ the standard 8-week cohort based protocol. To do this, we implemented a standardized 'introduction' during each session. This covered the basics of mindfulness, definitions, discussion of the triangle of awareness, and the SOBER breathing space, and a brief meditation that took new and returning participants through the SOBER breathing space. Group size ranged between 3 and 12 participants. Each session was led by two masters'-degree level clinicians. Each instructor underwent 200 hours of clinical training in mindfulness based interventions (e.g., Mindfulness based cognitive therapy, MBRP) and supervision prior to leading MBRP groups. Therapists had, on average, 4.5 years of experience leading groups and individual therapy sessions. Each session targeted a specific theme such as attentiveness to personal triggers, present focus awareness, acceptance versus avoidance, responding to emotional and physical experiences in skillful ways, intrusive thought recognition, or kindness in action. Participants were given 20–30 minutes of homework per day, including guided mindfulness meditations (provided on MP3 player) and some written exercises.

2.5.2. TAU

Control group (TAU) participants received treatment normally provided by the residential facility and were asked to attend up to eight extra social support groups (Alcoholics and Narcotics Anonymous) during their residential stay. This was intended to mitigate the possibility that treatment effects were due solely to the experimental group receiving "extra" attention. Attendance at extra support group meetings was equated to the number of hours the experimental group received

additional MBRP sessions. The basic treatment practice employed at the residential treatment center was a mix of cognitive behavioral treatment and 12-step approach to recovery. Individuals were asked to report how many Alcoholics and Narcotics Anonymous meetings they attended during the treatment phase and at all follow-ups. Like the experimental group, individuals in the TAU group were also asked about mindfulness practices.

2.6. Treatment fidelity

To prevent bias, therapists were not involved in follow-up assessments with the experimental group and were blind to participant responses on all outcomes during the treatment and follow-up phase. To assess treatment fidelity, the clinical supervisor rated both therapists using the MBRP Adherence and Competence Scale (MBRP-AC) on style/approach, delivery, attitude, inquiry, and adherence to the manual (Chawla et al., 2010). The average across all 16 observed sessions was 7.0 (SD = 1.43; range = 4 to 9). Although we did not reach 100% in terms of adhering to treatment components, this is likely due to sessions in which we did not have new participants (the component describing new participant orientation). The key concepts adherence scale is a count of behaviors used within each session that use the key concepts of MBRP to facilitate discussion and in-session exercises. Therapists averaged 20 (SD = 5.91) key concept behaviors per session (scores ranged from 8 to 30). Therapists were also rated on their general competence (e.g. therapists to respond to inquiry with open questions, without judgment, and with an open curiosity) as well as mindfulness therapist competence (e.g. ability to describe and explain misconceptions of mindfulness based practices) using the Therapist Style and Approach subscale. Overall therapists averaged 4.78 (SD = 0.176; range = 1 to 5) on the style/approach scale. The Overall Therapist Competence subscale captures therapists' global competence of treatment delivery including maintaining on topic, not striving, and working as a team during group sessions. On average, therapists scored 4.72 (SD = 0.264; range = 1 to 5) on the overall performance scale. This indicates therapists in this study reached excellent levels of competence on both therapist style/approach and overall therapist performance. As a comparison, Chawla et al. (2010) reported a therapist/approach mean rating of 3.95 (SD = 0.50) and overall therapist performance mean rating of 3.92 (SD = 0.42).

To assess treatment completion and engagement for both MBRP and TAU groups (see Table 2), we tracked participant attendance and how often they practiced mindfulness between sessions. Each participant was asked how many times they practiced mindfulness in the past two weeks. Individuals assigned to MBRP reported significantly higher number of times practicing mindfulness during the treatment phase than individuals assigned to TAU (t (51.3) = −2.31, p = .023). The majority of participants assigned to MBRP attended sessions and 90% received all eight MBRP sessions.

2.7. Measures

We used the web-based assessment tool Qualtrics LLC for all assessments. Time Line Follow Back (Sobell & Sobell, 1992) was used to assesses participants' recent (past 2 weeks) account of all self-reported measures of substance use. All other self-reported measures were in reference to the past two weeks. Both self-reported substance use and urinalysis were utilized during the treatment phase, however given the large number (85%) of participants that lived outside the study area, urinalysis was not possible during the post-treatment phase.

2.7.1. Control variables

To ensure our models adequately controlled for outside influences on days of substance use, stress, and craving we controlled for several institutional level variables. First, given some participants remained in the residential faculty longer or shorter than the 41-day average, we controlled for the number of days each participant spent in the facility. Further, given that some individuals were re-incarcerated (county jail or state prison) during the post-treatment phase, we controlled for the number of days each participant spent in jail, hospital, or prison at each time point. This helps adjust substance use data by adjusting for individuals that report zero days of use because they were not in the community.

2.7.2. Substance use

The *substance frequency scale* (SFS) (Dennis, Funk, Godley, Godley, & Waldron, 2004) measures the average percent of days of use for alcohol, heavy alcohol, cannabis, illicit drugs, and also days of problems associated with substance use. Higher scores represent increasing frequency of substance use days. An example item is "*in the past 2 weeks… how many days have you used any kind of alcohol*?" Participants respond with the number of days (range 0–14) they have used each substance. The SFS was reliable in both prior adolescent and young adult samples (Buchan, Dennis, Tims, & Diamond, 2002; Dennis et al., 2002; Lennox, Dennis, Scott, & Funk, 2006). Specifically, the SFS has shown strong reliability, validity, and strong relationship with abuse and dependence symptoms among a large sample of youth in substance use disorder treatment (Dennis et al., 2004). The SFS has good reliability and validity in the current sample (α = 0.85 and test-retest r = 0.94).

2.7.3. Craving

Items on the Craving Scale were from the GAIN assessment instrument and correspond to new DSM-5 criteria for craving. Composite scores were used as one of our primary outcome variables. The scale includes 14 items retained from the GAIN assessment tool (Dennis, Titus, White, Unsicker, & Hodgkins, 2003). An Example item include "*If I were using alcohol or other drugs, I would feel less nervous*" Each item is answered using "yes" (coded 1) or "no" (coded 0) and scores are summed across items. Reliability was α = 0.80 for this sample.

2.7.4. Stress

To measure stress, the 14-item *Perceived Stress Scale* (PSS; Cohen, Kamarck, & Mermelstein, 1983) was used. The PSS had good reliability in this sample (α = 0.83) and has been validated in studies with adolescents, young adults, and older adults. Participants are primed with the anchor "*in the past two weeks…*" "*How often have you been upset because of something that has happened unexpectedly*?" Items are answered on a 5-point Likert scale (0 = *Never*, 4 = *Very Often*).

Table 2
Participant treatment attendance and engagement in mindfulness practices.

	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8
MBRP attendance	100%	97.8%	95.6%	93.3%	93.3%	97.8%	93.3%	93.3%
Mindfulness practice	3.8 (3.0)	3.8 (3.1)	5.0 (4.2)	6.3 (6.9)	6.4 (6.5)	6.5 (5.2)	6.7 (5.9)	6.5 (5.6)
TAU attendance	100%	98.2%	99.2%	98.7%	96.3%	97.8%	96.6%	95.2%

Note: Sessions were held twice weekly, thus mindfulness practice refers to the Mean (SD) number of time participants practiced mindfulness between sessions (3–4 days between each session). TAU attendance is the proportion of individuals that attended the additional self-help meetings.

2.8. Analytic strategy

To assess change across stress, craving, and substance use, a taxonomy of bi-linear spline latent growth models were estimated[1] (Grimm, Ram, & Estabrook, 2016) in *Mplus* version 8 (Muthén & Muthén, 1998–2017). Bi-linear spline models are useful when there are reasons to separate time into discrete phases, which can be used to aid in explaining observed rates of change within each phase. Each discrete phase is usually a simple growth model and the segments that connect the growth models are called *knot* or *transition* points. In the current study we expect different growth trajectories to emerge during the treatment phase and post-treatment phase for both stress and craving. Specifically, bi-linear spline models were used to assess the effects of treatment assignment (MBRP vs TAU) during the treatment phase (slope 1) and post-treatment phase (slope 2) with the intercept centered at the pre-treatment assessment for craving and stress outcomes. Substance use is only modeled during the post-treatment phase due to no variability during treatment since each participant was in a residential facility. Thus substance use was modeled using basic latent growth curve models. All models tested for the presence of a quadratic effect during the post-treatment phase. Results suggested random intercept, linear slope, and quadratic slope provided the best fit to the data. To assess between-group differences in the intercept and growth in substance use, craving, and stress across both phases we regressed each on a dummy variable representing the experimental (MBRP = 1) and control (TAU = 0).

In addition to assessing the treatment effect on changes in stress, substance use, and craving across the two phases, we fitted a series of model constraints to assess between-group differences (e.g., simple slopes) in the outcomes at substantively meaningful points in time: 1) baseline, 2) treatment completion (i.e., end of the treatment phase), 3) mid-point (14 weeks), and 4) end of study (28 weeks, end of the post-treatment phase). To understand practical significance, we calculated standardized mean differences (Cohen's *d*) at all four time points, which provide descriptive indicators of effect size. Cohen's *d* was calculated with MBRP as the reference group, thus negative values favor the experimental condition. Given that multilevel models consist of two types of variability in the outcome variables (i.e., within-person and between-person), we scaled the given standardized effect size on the most substantively relevant level of variability. For instance, treatment-group differences at a given point in time were scaled on between-person variability (i.e., treatment status does not vary over time). In contrast, growth in the outcome over a particular span was scaled on within-person variability (i.e., time is a within-person predictor).

2.9. Mediation

To assess if changes in stress during the treatment phase mediated the association between treatment assignment and substance use and craving during the post-treatment phase, we fitted a series of structural equation mediation models (see supplemental figure; Cheong, MacKinnon, & Khoo, 2003). Specifically, we tested the extent to which the product of the *a* and *b* parameter estimates differed statistically from zero by bootstrapping its standard error and constructing 95% confidence intervals.

2.10. Power analysis

A priori Monte Carlo simulations (Muthén & Muthén, 2002) suggested a sample size of 90 is needed to be reasonably powered

[1] We also estimated multi-group bi-linear spline models as a robustness check. Multi group models allow us to consider varying means, variances, co-variances, and residual co-variances across groups. Results were robust to this method, and can be found in the supplemental materials.

Table 3
Means and standard deviations for substance use, craving, and stress at each time point for MBRP and TAU groups.

Variable	T0 *N* = 79	T1 *N* = 76	T2 *N* = 65	T3 *N* = 64	T4 *N* = 63	T5 *N* = 65	T6 *N* = 60	T7 *N* = 58	T8 *N* = 59	T9 *N* = 59	T10 *N* = 63	T11 *N* = 57	T12 *N* = 64	T13 *N* = 65	T14 *N* = 60
Stress															
MBRP	34.8 (7.03)	25.6 (6.74)	25.0 (7.05)	24.0 (7.81)	22.7 (5.61)	22.2 (6.66)	28.2 (3.08)	25.4 (8.38)	24.5 (8.38)	24.8 (8.21)	24.3 (7.25)	24.4 (8.76)	25.6 (8.35)	25.0 (11.5)	26.8 (10.6)
TAU	34.2 (8.69)	28.9 (9.82)	29.2 (8.39)	29.6 (8.51)	33.7 (7.88)	32.4 (10.5)	31.6 (7.33)	34.7 (10.2)	32.8 (12.3)	33.3 (9.65)	35.0 (8.18)	33.3 (9.49)	35.0 (8.88)	31.6 (13.7)	34.5 (9.85)
Craving															
MBRP	4.31 (2.87)	1.84 (1.82)	1.75 (1.95)	1.47 (1.83)	1.23 (1.59)	1.16 (1.35)	1.90 (2.58)	1.45 (1.81)	1.06 (1.28)	1.44 (1.93)	1.64 (2.20)	1.98 (3.16)	2.08 (3.58)	2.39 (3.87)	1.71 (2.62)
TAU	5.09 (2.56)	3.14 (2.46)	2.36 (2.39)	3.727 (3.67)	4.39 (3.56)	4.70 (3.89)	5.03 (4.20)	5.34 (4.48)	5.54 (4.36)	4.72 (4.11)	5.06 (4.03)	3.48 (3.35)	4.04 (4.19)	5.52 (4.76)	4.06 (4.16)
SFS															
MBRP	14.2 (11.4)	0.00 (0.00)	0.387 (2.32)	0.615 (1.81)	0.830 (1.47)	1.34 (2.79)	2.49 (5.90)	2.41 (4.88)	2.25 (4.56)	2.68 (6.06)	3.42 (7.18)	3.54 (8.17)	4.79 (9.15)	5.51 (9.48)	5.94 (12.9)
TAU	18.0 (12.7)	0.00 (0.00)	1.28 (4.60)	4.41 (9.71)	10.2 (13.1)	14.9 (15.5)	18.0 (16.1)	21.0 (14.6)	21.6 (15.5)	16.1 (13.0)	17.1 (12.4)	16.5 (11.5)	19.4 (14.4)	19.8 (16.4)	22.7 (15.4)

MBRP = mindfulness based relapse prevention; TAU = treatment as usual; SFS = substance frequency scale.

Table 4
Latent growth curve model for substance frequency scale. Parameter estimate (*SE*).

	Model 1 Unconditional growth Linear	Model 2 Unconditional growth Quadratic	Model 3 Conditional growth
Growth parameters			
Intercept	4.38 (0.99)*	2.99 (0.81)*	6.02 (1.16)*
Post-treatment phase linear slope	0.93 (0.18)*	2.24 (0.45)*	4.20 (0.61)*
Post treatment phase quadratic slope		−0.15 (0.05)*	−0.31 (0.07)*
Treatment effect			
Intercept			−5.37 (1.53)*
Post-treatment phase linear slope			−3.65(0.78)*
Post treatment phase quadratic slope			0.29 (0.08)*
Random effects (variance)			
Intercept	61.1 (13.6)*	41.1 (8.38)*	31.8 (6.81)*
Post-treatment linear slope	1.55 (0.39)*	11.2 (2.89)*	6.85 (1.94)*
Post treatment quadratic slope		0.10 (0.03)*	0.07 (0.02)*
Fit indices			
-2LL	5012.62	4937.36	4872.00
AIC	5046.63	4979.35	4936.22
BIC	5033.31	5029.10	5014.41
df	17	21	33

Note: Control variables are not shown for ease of readability. However, each model controlled for time spent in the residential facility, time spent in jail, prison or other facility, and baseline levels for substance frequency scale. Models for substance use did not model growth during the treatment phase due to no variability. This is due to participants being housed in a residential facility. Thus, substance use is modeled for the post-treatment phase only.
Model 1 is an unconditional linear latent growth model with random intercept and post-treatment slope.
Model 2 added a quadratic effect for the post-treatment phase slope (M1 to M2; Δ-2LL = 75.28, Δ df = 5, $p < .001$).
Model 3 added the experimental variable (1 = MBRP, 0 = TAU) to the model.
* $p < .05$.

(0.78–0.83) to detect modest to moderate between-person effect sizes (*d range* = 0.5–0.8) that are common in the relevant literature (Li et al., 2017). Because the research questions utilize several complex analyses (e.g., mediation), extant data with respect to plausible effect sizes are limited. Thoemmes et al. (2010) show that, by combining moderate and large effects into an indirect effect power of 0.80 is feasible with samples between 66 and 92.

3. Results

Means, standard deviations, and sample sizes at each time point can be found in Table 3.

3.1. Changes in substance use

Results from unconditional growth models indicated that, on average, substance use increased quadratically during the post-treatment phase—a modest uptick followed by an increasing plateau. (Table 4, Model 2). Notably, as illustrated in Fig. 2 (Table 4; Model 3), our conditional models indicated that this overall increase was driven almost exclusively by the control group. At the end of treatment, those assigned to the TAU group tended to show immediate increases in substance use ($b_{linear} = 4.20$, $p < .001$, $b_{quad} = -0.31$, $p < .001$) that peaked and subsequently plateaued around 13 weeks after treatment. This corresponds to an approximate 1.42 standard deviation increase between end of treatment and peak. The MBRP group's substance-use trajectories differed markedly ($b_{linear} = -3.65$, $p < .001$; $b_{quad} = 0.291$, $p < .001$). As shown in Fig. 1, on average, MBRP participants abstained from substance use immediately after treatment, and maintained this flat trajectory throughout the remainder of the study (i.e., simple slopes: $b_{linear} = 0.55$, $p = .26$; $b_{quad} = -0.02$, $p = .76$). The diverging trajectories between the MBRP and TAU groups manifested in effects size that ranged from moderate ($d_{tx\ completion} = -0.58$) to rather large ($d_{12\ weeks} = -1.8$; $d_{28\ weeks} = -1.1$).

3.2. Changes in craving

As indicated by our conditional models (Table 5; Model 3; Fig. 3) participants reported statistically significant declines in their level of craving during the treatment phase ($b_{TAU} = -1.12$, $p < .01$; $b_{MBRP} = -1.48$, $p < .001$). These declines were statistically identical across treatment conditions ($b = -0.213$, $p = .68$). Notably, these respective craving trajectories diverged markedly upon leaving treatment ($b_{linear} = -0.86$, $p < .001$; $b_{quad} = 0.07$, $p < .001$). On average, those assigned to the MBRP condition largely maintained their low levels of craving throughout the remainder of the 28- week study period (Simple slopes: $b_{linear} = 0.26$, $p = .11$; $b_{quad} = -0.02$, $p = .29$). In contrast, those assigned to the TAU condition showed rather immediate and

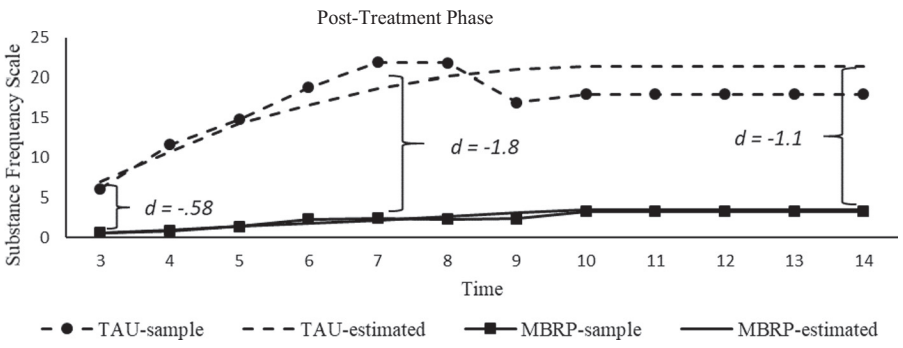

Fig. 2. Mean level change for the substance frequency scale from treatment completion to end of study. Both estimated (noted as estimated) and raw means (noted as sample) are displayed. Time points represent 2 week intervals. Data analyzed for substance use was during the post-treatment phase only given participants were in a residential facility during the treatment phase, and thus unable to use resulting in zero variance for the first three time points.

Table 5
Bi-linear spline models for craving. Parameter estimate (*SE*).

	Model 1 Unconditional growth Linear	Model 2 Unconditional growth Quadratic	Model 3 Conditional growth
Growth parameters			
Intercept	4.34 (0.28)*	4.39 (0.28)*	4.87 (0.43)*
Treatment phase linear slope	−1.04 (0.17)*	−1.25 (0.15)*	−1.12 (0.23)*
Post-treatment phase linear slope	0.13 (0.04)*	0.39 (0.11)*	0.85 (0.015)*
Post treatment phase quadratic slope		−0.03 (0.01)*	−0.07 (0.01)*
Treatment effect			
Intercept			−0.86 (0.57)
Treatment phase linear slope			−0.21 (0.31)
Post-treatment phase linear slope			−0.85 (0.19)*
Post treatment phase quadratic slope			0.07 (0.02)*
Random effects (variance)			
Intercept	3.64 (1.05)*	4.03 (1.06)*	3.85 (1.03)*
Treatment phase slope	1.11 (0.35)*	0.67 (0.31)*	0.66 (0.30)*
Post-treatment linear slope	0.10 (0.03)*	0.53 (0.15)*	0.35 (0.11)*
Post treatment quadratic slope		0.004 (0.00)*	0.003 (0.001)*
Fit indices			
-2LL	4252.09	4178.33	4148.60
AIC	4272.09	4208.30	4186.62
BIC	4295.90	4244.10	4231.86
df	10	15	19

Note: Control variables are not shown for ease of readability. However, each model controlled for time spent in the residential facility and time spent in jail, prison or other facility.
Model 1 is an unconditional bilinear spline growth model with random intercept, treatment slope, and post-treatment slope.
Model 2 added a quadratic effect for the post-treatment phase slope (M1 to M2; Δ-2LL = 73.75, Δ df = 5, $p < .001$).
Model 3 added the experimental variable (1 = MBRP, 0 = TAU).
* $p < .05$.

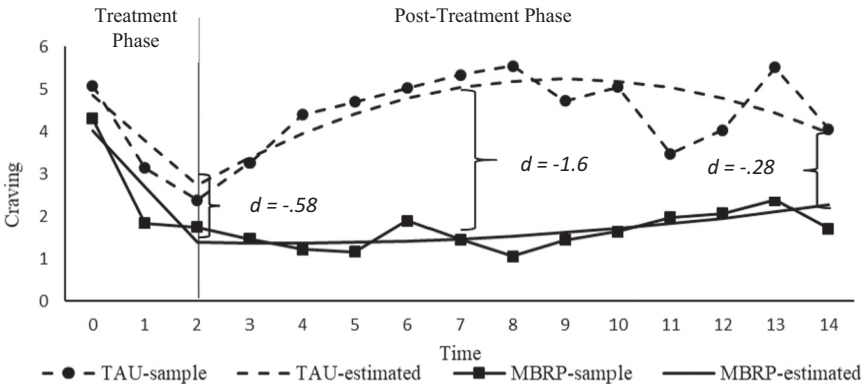

Fig. 3. Mean level change in craving from baseline to end of study. Both estimated (noted as estimated) and raw means (noted as sample) are displayed. Time points represent 2 week intervals. From time 0 to time point 2 participants were in treatment at the residential facility (e.g., treatment phase). Time point 3 to time point 14 participants were being assessed in the community (e.g., post-treatment phase).

substantial increases in their craving levels, before plateauing approximately 14 weeks post-treatment (Simple slopes: $b_{linear} = 0.85$, $p < .001$; $b_{quad} = -0.07$, $p < .001$). This corresponds to an approximate 1.40 standard deviation increase in craving from leaving treatment to 12 weeks post-treatment at the peak. As shown by the vertical distance between the trajectories (marked by brackets in Fig. 2), the diverging trajectories between the MBRP and TAU groups manifested effects sizes that ranged from moderate at treatment completion ($d_{\text{tx completion}} = -0.58$), rather large at the mid-point ($d_{12\text{ weeks}} = -1.6$) to small at the end of the study ($d_{28\ weeks} = -0.28$).

3.3. Changes in stress

Unlike the decreases shown for craving, only those in the MBPR group showed statistically significant (linear) improvements in their stress levels during the treatment phase (MBRP: $= b_{linear} = -2.83$, $p < .001$; TAU: $b_{linear} = -1.60$, $p = .18$). See Table 6, Model 3.

Like craving, those in the MBRP group showed statistically less positive growth rates than the TAU group ($b_{linear} = -1.34$, $p = .03$) upon leaving treatment. Specifically, they tended to maintain their lower, treatment-acquired stress levels throughout the remainder of study (28 weeks, post-treatment). In contrast, during the post-treatment phase, those assigned to the TAU group tended to show rather immediate increases in their stress levels that gradually slowed (simple slope: $b_{linear} = 1.36$, $p = .03$), before plateauing around 17 weeks post-treatment. This corresponds to an approximate 1.2 standard deviation increase in stress from the time participants left treatment and 14 weeks post-treatment at the peak. As illustrated by the brackets in Fig. 4, the diverging trajectories between the MBRP and TAU groups manifested effects sizes that ranged from moderate ($d_{tx\ completion} = -0.77$) to rather large ($d_{12\ weeks} = -1.7$; $d_{28\ weeks} = -1.3$).

3.4. Stress mediation

We first assessed if changes in stress during the treatment phase influence craving during the post-treatment phase (see Table 7). Results indicate a non-significant indirect effect for stress between treatment assignment and craving. However, the same model for substance use showed a significant indirect effect. Using the standardized parameters (*Unstandarized* $= -.780, 95\%\ CI\ [-1.45, -.114]$, *standarized* $= -.449$) this

Table 6
Bi-linear spline models for stress. Parameter estimate (*SE*).

	Model 1 Unconditional growth Linear	Model 2 Unconditional growth Quadratic	Model 3 Conditional growth
Growth parameters			
Intercept	32.6 (0.87)*	32.6 (0.87)*	33.4 (1.87)*
Treatment phase linear slope	−3.02 (0.52)*	−3.20 (0.54)*	−1.60 (1.20)
Post-treatment phase linear slope	0.44 (0.12)*	0.78 (0.30)*	1.36 (0.65)*
Post treatment phase quadratic slope		−0.04 (0.03)	−0.08 (0.06)*
Treatment effect			
Intercept			1.23 (1.61)
Treatment phase linear slope			−2.83 (1.05)*
Post-treatment phase linear slope			−1.34 (0.57)*
Post treatment phase quadratic slope			0.08 (0.05)
Random effects (variance)			
Intercept	6.81 (13.8)	4.03 (1.06)*	4.96 (3.91)
Treatment phase slope	5.01 (4.63)	0.67 (0.31)*	5.12(4.54)
Post-treatment linear slope	0.79 (0.19)*	0.53 (0.15)*	2.83 (1.04)*
Post treatment quadratic slope		0.004 (0.001)*	0.02 (0.01)*
Fit indices			
-2LL	6368.82	6347.61	6288.58
AIC	6416.82	6405.69	6370.58
BIC	6473.98	6474.69	6468.25
df	24	27	41

Note: Control variables are not shown for ease of readability. However, each model controlled for time spent in the residential facility and time spent in jail, prison or other facility.
Model 1 is an unconditional bilinear spline growth model with random intercept, treatment slope, and post-treatment slope.
Model 2 added a quadratic effect for the post-treatment phase slope (M1 to M2; Δ-2LL = 21.21, Δ df = 5, $p < .001$).
Model 3 added the experimental variable (1 = MBRP, 0 = TAU) to the model.
* $p < .05$.

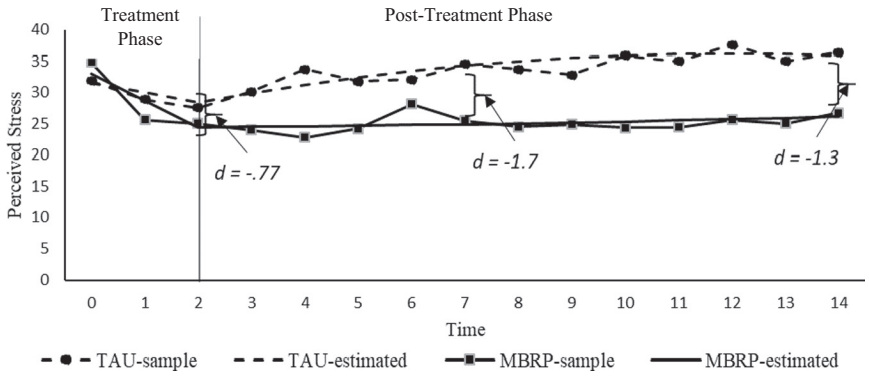

Fig. 4. Mean level change in perceived stress from baseline to end of study. Both estimated (noted as estimated) and raw means (noted as sample) are displayed. From time 0 to time point 2 participants were in treatment at the residential facility (e.g., treatment phase). Time point 3 to time point 14 participants were being assessed in the community (e.g., post-treatment phase).

indicates that post-treatment substance use is expected to decrease by 0.45 standard deviations for individuals assigned to MRBP (versus TAU) via decreases in perceived stress during treatment.

4. Discussion

This randomized controlled trial represents the first study to investigate the effect of MBRP among a sample of marginalized young adults receiving residential substance use disorder treatment. In contrast, most research in this area has focused on college populations or older adults in residential treatment facilities (Davis et al., 2017; Li et al., 2017; Witkiewitz et al., 2014). Further, despite the relative severity of this study population and the known transient nature of young adults, the current study was able to successfully engage participants in MBRP sessions and had comparable attrition rates (ranging from 0% to 29%) to other substance use disorder treatment studies (Bowen et al., 2014).

4.1. Implications of main effect findings

Findings from this study supported several of our hypotheses. In terms of craving (H1), there were no differences in craving between MRBP and TAU participants during the treatment phase, indicating both groups had similar decreases in craving. However, individuals assigned to MBRP maintained lower craving scores compared to those assigned to TAU throughout the post-treatment phase. Our results follow suit with prior studies investigating the effect of mindfulness based interventions on craving across a variety of samples. For example, Witkiewitz et al. (2014) reported significant effects on craving for female offenders assigned to MBRP compared to those assigned to Relapse Prevention only. Our study found significant mean differences during the post-treatment phase. This implies that adding mindfulness to the typical residential treatment regimen may help better prepare young adults for the environmental relapse risks they face upon exiting.

We found support for our second hypothesis (H2) related to post-treatment substance use. That is, substance use increased relatively rapidly, immediately following treatment discharge for individuals assigned to TAU with sustained low endorsement of substance use over the 6-month follow-up period for those assigned to MBRP. However, we did note a slowing of this acceleration for those assigned to TAU, indicating the groups were beginning to get closer together at study completion. These results echo findings from a recent meta-analysis

Table 7
Model based approach for stress mediation.

	Model 1 Craving			Model 2 Substance use		
	Parameter (SE)	*p*-Value	95% CI	Parameter (SE)	*p*-Value	95% CI
A path	−0.422 (0.193)	.022	−0.820, −0.064	−0.608 (0.180)	.001	−0.961, −0.256
B path	0.285 (0.103)	.006	0.082, 0.487	1.28 (0.409)	.002	0.480, 2.09
C′ path	−0.053 (0.081)	.510	−0.212, 0.105	0.314 (0.338)	.353	−0.348, 0.967
Total effect	−0.179 (0.066)	.007	−0.309, −0.050	−0.467 (0.398)	.241	−1.24, 0.313
Indirect effect	−0.126 (0.065)	.050	−0.254, 0.001	−0.780 (0.340)	.022	−1.45, −0.114

Note: each model allowed for co-variation between intercepts and slopes. Unstandardized coefficients are displayed. 95% CI = 95% confidence interval.

that found small effects ($d = -0.28$) for mindfulness interventions on substance use (when compared to control conditions (e.g., TAU; Li et al., 2017). More importantly, given our sample was primarily illicit drug users (e.g., heroin and methamphetamine), our results also echo findings from Li et al. (2017), which found a Cohen's d of −0.51 for mindfulness interventions in reducing opiate abuse. While results from the current study cannot be directly compared to prior studies in terms of sample (e.g., marginalized young adults), results are parallel to previous studies investigating the effect of MBRP on substance use outcomes with adult populations. For example, Witkiewitz et al. (2014) found a 96% decrease in the risk for relapse for individuals assigned to MBRP compared to individuals assigned to Relapse Prevention among female offenders in residential treatment. Results also indicated at 15-week follow up individuals assigned to MBRP showed significantly fewer days of drug and alcohol use ($d = 0.36$–0.45), and significantly fewer legal problems ($d = 1.18$) compared to individuals assigned to relapse prevention. Further, Bowen et al. (2014) randomly assigned adults assigned to MBRP ($n = 103$), relapse prevention ($n = 88$), and treatment as usual (TAU; $n = 95$). Compared to TAU, individuals assigned to MBRP and relapse prevention only showed a 54% decreased risk of relapse for drug use and a 59% decrease risk of relapse to heavy drinking at 6-month follow-up. Results from these seminal studies on MBRP and the current study continue to add to a pattern of sustained gains of important treatment outcomes for MBRP versus TAU and other treatment modalities.

In line with H3, we found a large, clinically-relevant effect for stress; individuals assigned to MBRP had significantly lower stress scores during both the treatment and the post-treatment phase. Our findings are in line with Li et al. (2017), who reported that reductions in stress had the largest effect size across all studies assessing effectiveness of mindfulness interventions for substance use disorders (Cohen's $d = -1.12$). Given stress is one of the most well-known contributors to initiation and continuation of substance use (Shonkoff & Garner, 2012; Sinha, 2008), assessing how mindfulness treatment targets reduction in stress is vital for understanding recovery processes.

4.2. Mechanisms of behavior change

Over the past five years researchers have become interested in the potential mechanisms that may aid in explaining the effect of mindfulness based interventions on substance use problems and related behaviors (e.g., craving; Witkiewitz et al., 2013). Prior research has found that greater mindful acceptance and nonjudgement partially explained changes in substance use for individuals assigned to MBRP versus Relapse Prevention (Witkiewitz & Bowen, 2010). Garland, Roberts-Lewis, Tronnier, Graves, and Kelley (2016) found that changes in dispositional mindfulness fully mediated the association between treatment assignment (Mindfulness Oriented Recovery Enhancement vs. other treatments) and craving. Results from the current study provide further support for mechanisms of behavior change in mindfulness interventions. Specifically, we found partial support for our mechanisms hypotheses. Specifically, we did not find support for H4, indicating craving did not mediate the association between treatment assignment and post-treatment substance use. This is in contrast to recent research on the effects on MBRP (and MBIs in general) on craving. There have been two proposed pathways to aid in explaining the association between mindfulness, stress, and craving. The first pathway is through a "top down" approach in which individuals exhibit executive control over craving or urges to use and the second, a "bottom up" approach, in which individuals change their subjective experience of craving (Westbrook et al., 2011; Witkiewitz et al., 2013). In a secondary analysis Witkiewitz and Bowen (2010) sought to test moderated mediation pathways between negative affect, craving, and post-treatment substance use outcomes. Results indicated that MBRP attenuated the associations between self-reported negative affect scores and craving, with craving significantly mediating the relation between treatment assignment and days of drug and alcohol use at follow up. Interestingly, the relationship between negative affect and post-treatment substance use was mediated by craving among the TAU group and not MBRP participants. Further analyses revealed that the differences in craving between MBRP and TAU groups were partially explained by greater mindful acceptance, awareness and nonjudgement among individuals assigned to MBRP (Witkiewitz et al., 2013). Thus, future research may wish to continue examination of the effects of MBRP or mindfulness based interventions on craving and its relation to long term treatment outcomes.

However, we did find support for H5, such that reductions in stress mediated the association between treatment assignment and substance use. These results support the notion that reducing one's stress can act as an important mechanism in the recovery cycle (Sinha, 2001). From a psychological perspective, stress can result from challenging events or environmental conditions that produce acute psychological reactions. These reactions are typically augmented through psychoactive substances. In general, when under stress, the body activates an automatic or "auto pilot" response typically in the form of rumination, negative thoughts, assumptions about what will happen, and impulsivity (Esch, 2014). The MBRP curriculum has a strong focus on acknowledging when people enter 'auto pilot' when under stress and provides alternatives to remaining in this state. For example, one way MRBP may mitigate effects of stress is through the practice of reducing rumination and enhancing emotional regulation. Through practices such as the "SOBER (Stop, Observe, Breathe, Expand, Respond) breathing space" and allowing "thoughts to be thoughts", MBRP teaches individuals *not* to push negative thought processes aside (which can activate a stress response via neglecting internal emotionality), but to sit with the negative thoughts in a safe space. The current study provides further support for the effects of mindfulness based interventions on psychological stress.

While the current study did not test physiological mechanisms, it is possible that reduced perceived stress is associated with changes in the stress response system. That is, it may be that the skills learned in MBRP influence neurological (Hypothalamic Pituitary Adrenal axis) aspects of the stress response systems which aid in reduced craving and return to use. At the epicenter of mindfulness based practices is the potential for

physiological, psychological and neurobiological stress reduction (Jung et al., 2010; Marchand, 2012; Mohan, Sharma, & Bijlani, 2011; Stefano, Fricchione, & Esch, 2006). For example, researchers have shown that when someone enters a meditative state there is a potential to elicit a "relaxation response" (Some researchers have posited that measuring salivary alpha amylase is a proxy for the relaxation response; Lazar et al., 2000) which is thought to be an antagonist of the 'stress response' (Esch, 2014). Future research may benefit from a close look at how the relaxation response aids individuals in residential substance use disorder treatment. Other researchers have used similar proxies for stress such as high frequency heart rate variability (e.g., cardiac vagal tone) to understand the effects of treatment on the stress response system (Carroll & Lustyk, 2018; Eddie, Kim, Lehrer, Deneke, & Bates, 2014; Eddie, Vaschillo, Vaschillo, & Lehrer, 2015). Theories suggest that cardiac vagal control (ability to self-regulate) may require sustained attention and emotional attenuation. Prior research has found vagal control to increase and lower levels of heart rate reactivity for individuals assigned to an 8-week MBRP intervention compared to TAU (Carroll & Lustyk, 2018). This means that MBRP may be addressing internal negative emotionality, rumination, and stress for individuals in treatment for substance use disorders. With some researchers finding that stress induced craving and negative emotionality was predictive of quicker time to relapse (Sinha, Garcia, Paliwal, Kreek, & Rounsaville, 2006), it may be that individuals assigned to MBRP have successfully mitigated the effects of dysregulated stress response systems thus leading to decreased desire (craving) and substance use. This falls in line with Witkiewitz et al. (2013) who hypothesized that long-term effects of MBRP may be observable through changes in physiological processes and perceived stress, which may improve long-term treatment outcomes. Future research may wish to explore how mindfulness based interventions influence proxy measures of stress such as heart rate variability during the intervention phase to explore how changes in stress reactivity during treatment are associated with proximal and distal outcomes.

4.3. Limitations and conclusion

This study had several limitations. First, the small sample size may have influenced the power to detect effects of interest and make statements regarding null growth. While we were able to detect small to moderate treatment effects, a larger sample size and replication are warranted to determine reliability of both main and mediation effects. Second, the present study was limited by a lack of biochemical measures of abstinence. However, prior studies have found that self-reported substance use is highly correlated with biochemical results and a reliable way to assess treatment effects (Chan, 2009). Third, with respect to the study design, the treatment facility provided ample opportunity for participants to share their treatment experience across conditions. Participants assigned to MBRP were given explicit instructions not to share the material being learned in the MBRP sessions with their peers. No participant could switch treatment assignments after randomization was completed. Additionally, we adapted the original manualized MBRP workbook. The original format is a closed group and 8 two hour sessions. We used a rolling admissions framework and only 1.5 h per session. While the classes were shorter (given time constraints at the residential facility), all aspects of the curriculum were included. However, to address the different time constraints, several modules were shortened. Finally, supervision of adherence and competence was conducted by one rater. Having multiple raters is beneficial to avoid bias in rater scoring and for validity checks (e.g., rater agreement).

In conclusion, this is the first study to provide evidence and support for the use of MBRP among high risk, marginalized young adults in residential substance use disorder treatment. Results show moderate to large effect sizes on factors that are integral to reducing relapse among a sample of individuals with low abstinence rates. Further, this study provided additional support that MBRP can be used as an active treatment, and not just as an aftercare protocol. It is also the second study to investigate the use of MBRP using a rolling group admission processes (Witkiewitz & Bowen, 2010), which is more likely to be disseminated in community based settings compared to the closed group format. Results demonstrated that MBRP is effective in reducing perceived stress during the treatment phase and, more importantly, *maintaining* lower stress throughout the post-treatment phase. Finally, this is the first study to provide support for changes in stress as an active mechanism contributing to lower substance use. Overall, findings suggest that MBRP is an appropriate and integrative therapy designed to reduce stress, negative emotion, and substance use among a sample of marginalized young adults.

Acknowledgements

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsat.2018.05.002.

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