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Mindfulness training for smoking cessation: moderation of the relationship between craving and cigarette use

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Abstract

Background—Smoking is the leading cause of preventable death in the US, while abstinence rates remain modest. Smoking has been shown to be perpetuated by operant conditioning, notably negative reinforcement (e.g., smoking to relieve negative affective states). Mindfulness training (MT) shows promise for smoking cessation, by potentially altering an individual's tendency to smoke in response to craving. The purpose of this study was to examine the effects of MT and mindfulness practice on the relationship between smoking and craving after receiving four weeks of MT.

Methods—33 adults received MT as part of a randomized trial for smoking cessation. Individuals in the MT condition recorded formal and informal mindfulness practice during treatment using daily diaries.

Results—Analyses showed that strong correlations between craving and smoking at baseline ($r=0.582$) were attenuated at the end of treatment ($r=0.126$). Mindfulness home practice significantly predicted cigarette use (formal: $B=-1.21$, $p=0.007$; informal: $B=-1.52$, $p<0.0001$) and informal practice moderated the relationship between craving and smoking at the end of treatment ($B=0.52$, $p=0.03$).

Conclusions—These findings suggest that MT may be effective as a treatment for smoking cessation and that informal mindfulness practice predicts a decoupling of the association between craving and smoking.

Keywords

tobacco; nicotine dependence; mindfulness; craving; associative learning; negative reinforcement; incentive salience; addiction

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Contributors.

Author Brewer designed the study. Author Brewer wrote the protocol and conducted the study. Authors Brewer, Mallik, and Thornhill collected data. Authors Brewer, Elwafi, Mallik and Witkiewitz analyzed the data. Authors Brewer, Elwafi, Mallik, Thornhill, and Witkiewitz interpreted the data. Authors Brewer, Elwafi, and Witkiewitz wrote the manuscript. Authors Brewer, Elwafi, Mallik, Thornhill, and Witkiewitz edited the manuscript. All authors have approved the final manuscript.

Conflict of Interest.

None.

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1. INTRODUCTION

Cigarette smoking is the leading cause of preventable death and disability in the United States (Center for Disease Control and Prevention, 2011). 50% of smokers attempt to quit annually both on their own (i.e., without formal treatment) and with formal treatment. Among those smokers who attempt quitting without formal treatment, only 3–5% remain abstinent for 6–12 months (Center for Disease Control and Prevention, 2011; Hughes et al., 2004).

Nicotine may have a number of behaviorally reinforcing effects that contribute to both the onset and maintenance of psychological dependence. A stimulus may be considered reinforcing if it increases a response or behavior associated with obtaining that stimulus. The reinforcing effects of nicotine may be positive, such as rewarding psychoactive effects of nicotine [e.g., the enhancement of attention and concentration and the blunting of appetite for maintaining lower body weight (Heishman et al., 1994; Perkins, 1993), or negative, such as the alleviation of aversive states, e.g., relief from withdrawal symptoms, or reduction of anxiety, sadness, or fatigue (Carey et al., 1993; Carmody, 1992; Kassel et al., 2003; Piasecki et al., 1997; Wu and Anthony, 1999)]. Through these positively and negatively reinforcing conditions, associative memories are formed (Figure 1a; Bevins and Palmatier, 2004; Kandel and Davies, 1986; Leknes and Tracey, 2008; Piasecki et al., 1997). Subsequent cues that trigger these affective states may then become associated with smoking, and induce craving for a cigarette (Bargh and Chartrand, 1999; Curtin et al., 2006). Importantly, by virtue of the same positive and negative reinforcement, these affective states themselves can lead to craving (Willner et al., 1995; Willner and Jones, 1996), perhaps accounting for the inconsistent findings in support of cue-induced craving leading to relapse (Perkins, 2009; Tiffany, 1990; Tiffany and Carter, 1998; Tiffany and Conklin, 2000). As such, both external cues and internal affective states can trigger craving to smoke. Craving then becomes the central hub of this associative learning loop, as cues lead to craving, craving leads to smoking, and smoking reinforces the salience of future external cues and affective states (Baker et al., 2004; Berridge and Aldridge, 2009; Brewer et al., 2012, 2011; Curtin et al., 2006; Robinson and Berridge, 2003; Tiffany, 1990).

Robinson and Berridge postulated that to understand addiction, we need to understand the process by which “addicts develop an obsessive craving for drugs, a craving that is so irresistible that it almost inevitably leads to drug seeking and drug taking” (Robinson and Berridge, 1993). Indeed, craving and subsequent smoking have long been closely associated amongst daily smokers (Baker et al., 2004; Carter et al., 2008; Killen et al., 1997; Shiffman et al., 1997; Tiffany, 1990). For example, both adults and adolescents who report higher levels of craving also exhibit higher levels of daily cigarette consumption (Bagot et al., 2007; Pomerleau et al., 2000; Prokhorov et al., 2005).

Craving is potentially the most difficult obstacle to overcome for smokers attempting to quit (Killen et al., 1997; West and Schneider, 1987). Intense and unremitting craving often precedes the initial lapse following a cessation attempt and a number of studies have shown that increases in the intensity of craving can accurately predict lapse and relapse risk (Herd et al., 2009; Killen et al., 1997; Piasecki, 2006; Shiffman et al., 1997). For example, in a study of treatment-seeking smokers, for each standard deviation increase in craving on the target quit date, the risk of lapsing rose by 43% on that day, and 65% on the following day (Ferguson et al., 2006).

The sheer number of cues that smokers can associate with positive and negative affective states, in addition to neutral states, greatly complicates individuals’ attempts to quit smoking. Many current behavioral treatments for smoking cessation teach individuals to

avoid cues, divert their attention away from cravings, substitute other activities for smoking, or to promote positive affective states by practicing relaxation or exercising (Fiore et al., 2008; Lando et al., 1990). It is hypothesized that these treatments may not be successful in targeting the addictive loop (Figure 1b, black arrows). These treatments have shown only modest success, as abstinence rates in the United States have remained under 30% for the past 30 years (Fiore et al., 2008). This is perhaps partly due to the ubiquity of cues; avoiding them often takes a lot of cognitive effort, which may be unavailable during strong affective or 'ego-depleted' states (Baumeister et al., 1998; Muraven and Baumeister, 2000; Tiffany et al., 2000). Also, substitutions are not always available or effective as they may treat "around" craving rather than directly targeting it (Figure 1b, blue arrows). Taken together with the basic scientific findings of the central role of craving in addiction, the shortfalls of current treatments point toward the development of new approaches that directly target and dismantle the core links of the addictive loop. Recent evidence suggests that treatments such as mindfulness training (MT) may confer these benefits (Bowen et al., 2009; Brewer et al., 2012, 2011).

In a clinical context, mindfulness can be described as an awareness of moment-to-moment experience arising from attention that is characterized by curiosity toward and acceptance of these present-moment experiences (Bishop et al., 2004; Kabat-Zinn, 2003). Mindfulness training is derived from Buddhist practices, and has been adapted for use in Western cultures in a variety of ways, taking the form of Mindfulness-based Stress Reduction, Mindfulness-based Cognitive Therapy, and Mindfulness-based Relapse Prevention (Bowen et al., 2009; Kabat-Zinn, 1982; Marlatt and Donovan, 2005; Teasdale et al., 2000). Importantly, mindfulness directly targets wanting/craving, postulating that this causes the majority of unhealthy behaviors and thought patterns (Brewer et al. 2012; Thanissaro 2010). MT has been explored as a treatment for pain (Kabat-Zinn, 1982; Kabat-Zinn et al., 1985), anxiety disorders (Evans et al., 2008; Kabat-Zinn et al., 1992; Roemer and Orsillo, 2002), and depression (Segal et al., 2010; Teasdale et al., 2000) among others.

Recently, MT has been evaluated as a treatment for addictions (Bowen et al., 2009; Brewer et al., 2010; Zgierska et al., 2008) and specifically smoking (Bowen and Marlatt, 2009; Brewer et al., 2011; Davis et al., 2007), though the majority of studies have been of pilot nature (Zgierska et al., 2009). For example, Davis and colleagues reported that 10 of 18 participants who had received MT were abstinent six weeks after quitting (Davis et al., 2007). In another trial, Bowen and colleagues found that after providing brief mindfulness-based instructions to college students (to accept thoughts non-judgmentally, and to pay attention to urges and accompanying sensations without trying to change or get rid of them), the students smoked significantly fewer cigarettes seven days post-intervention compared to students who did not receive the instructions (Bowen and Marlatt, 2009). Interestingly, this was despite the fact that the two groups did not differ significantly on measures of urges.

More recently, Brewer and colleagues conducted a randomized clinical trial in which participants were randomized to receive either MT or Freedom From Smoking (FFS, a cognitive behavioral treatment developed by the American Lung Association) as stand-alone treatments for smoking cessation (Brewer et al., 2011). Compared to participants who received FFS, those who received MT showed a greater rate of reduction in cigarette use and greater abstinence rates that were maintained 4 months later (31% vs. 6%, $p = 0.01$; Brewer et al., 2011). Importantly, they found significant correlations between the amount of home mindfulness practice and smoking cessation in the MT group, where none were found in the FFS group (which engaged in other forms of home practice, such as relaxation training). In other words, the more individuals in the MT group practiced, the better they were able to quit, whereas no matter how much practice the FFS group did, it didn't affect their smoking behavior. Drawing upon what is known about associative learning in addictions, if craving is

core to the addictive process and functions through strengthening the associative learning loop, one might hypothesize that MT would affect the strength of the relationship between craving and smoking behavior (as it is theorized to do). By learning non-judgmental observation of craving itself through MT, one might decouple the associative link between craving and subsequent behavior. In other words, individuals may learn to notice affective states and urges to smoke, and just allow them to arise and pass without habitually or impulsively acting on them.

In this report, we evaluated the relationship between craving and cigarette use before and after individuals received MT for smoking cessation. The primary objective was to determine whether the relationship between craving and smoking changed with mindfulness training, and if it was affected by the amount of formal and informal mindfulness home practice that individuals performed. We hypothesized that the amount of home practice that individuals performed would be directly related to the diminution of the craving/smoking relationship: the more individuals practiced, the more craving and smoking would be dissociated.

2. METHODS

2.1 Study Design

This analysis examined data collected during a randomized controlled trial evaluating the efficacy of MT for smoking cessation (Brewer et al., 2011). The study was a randomized, controlled trial with a 4-week treatment period (suggested quit day was the end of week 2), and post-treatment follow-up interviews at 6 weeks, 3 and 4 months after treatment initiation. This protocol was approved by the Yale University and Veteran's Administration institutional review boards. It is also in accordance with the Helsinki Declaration of 1975, as revised in 2000.

2.2 Study Population

Eligible subjects were 18 – 60 years of age, smoked >10 cigarettes/day, had fewer than 3 months of abstinence in the past year, and reported an interest in quitting smoking. Participants were excluded if they currently used psychoactive medications, had a serious or unstable medical condition in the past 6 months, or met DSM-IV criteria for other substance dependence in the past year. Given our hypothesis that mindfulness home practice would affect the relationship between craving and smoking, the analyses in the current report were limited to individuals randomized to the MT intervention (Brewer et al., 2011).

2.3 Intervention

MT was manualized and adapted for smoking cessation from a previous MT manual for drug relapse prevention (Bowen et al., 2009; Brewer et al., 2009). The main themes of momentary awareness and acceptance of cravings and affective states were introduced and reinforced throughout the training (Kabat-Zinn, 1982). Sessions were delivered by an experienced instructor in a group format twice weekly over 4 weeks, for a total of 8 sessions. Suggested quit day was session 4 (end of week 2). For specific details of the training, please see Brewer et al (2011).

2.4 Home practice

Home practice was suggested after each of the 8 sessions as a combination of formal and informal MT practices (Brewer et al., 2011). *Formal practices* consisted of: 1) the 'body scan' which teaches individuals to systematically pay attention to different parts of their bodies as a way to reduce habitual mind-wandering and strengthen their attentional capacities, 2) 'loving-kindness' meditation, which is practiced by wishing well for oneself

and others, usually by repeating a phrase such as ‘may I be happy, may I be healthy, may I be free from inner and outer harm’ and 3) ‘awareness of breath’ meditation in which attention is focused on the breath, with the additional intention of helping individuals become more aware of the present moment and refrain from habitually engaging in self-related pre-occupations concerning the future or the past. *Informal practices* consisted of 1) setting daily aspirations, 2) performing daily activities mindfully, and 3) techniques designed to mindfully work with cravings (e.g., RAIN: Recognize, Accept, Investigate, and Note mind-states, emotions, and body sensations from moment-to-moment). During treatment, subjects were instructed to record the amount of formal (number of minutes) and informal (number of times) mindfulness practice each day using structured daily diaries.

2.5 Study Data Points

Craving levels and smoking status were assessed at baseline, at the end of treatment, and at follow-up interviews at 6 weeks, 3 months, and 4 months post-treatment initiation. Primary endpoints of the initial study were 1) end of treatment and 2) 4 month follow-up (Brewer et al., 2011). Home practice was recorded daily during the 4 weeks of treatment. A research assistant who was not involved in treatment delivery checked diary entries twice weekly to ensure adherence. Data were entered into an electronic database using Teleforms, and verified by hand.

2.6 Craving

Subjective craving was assessed using the Questionnaire of Smoking Urges – Brief (QSU-B) (Cox et al., 2001; Tiffany and Drobes, 1991). The QSU-B is a 10-item questionnaire that asks subjects to rate, on a seven-point scale, how strongly they disagree or agree with each question (e.g., “I have an urge for a cigarette now”).

2.7 Smoking Status

Subjects were instructed to report the number of cigarettes they smoked each day during treatment as part of their structured daily diaries. Daily cigarette use was averaged across each week to generate an average number of daily cigarettes smoked per week. These were checked twice weekly at in-person visits by a research assistant who was not involved in treatment delivery. Each verification check included exhaled carbon monoxide measurements. Reported abstinence was verified by an exhaled carbon monoxide measurement of 10 parts per million (Brewer et al., 2011).

2.8 Statistical Analysis

Longitudinal data were analyzed using the full sample of MT treatment-exposed subjects. Demographic and baseline clinical characteristics were examined using ANOVA and chi-square analyses, using SPSS 19. Incomplete data were handled using the last observation carried forward technique (LOCF), in which missing values are replaced with the last complete observation for that case. Given its simplicity and ease of use, LOCF is a long-standing approach specific to longitudinal clinical trials (Enders, 2006; Hedeker et al., 2007; Wood et al., 2004). Multiple imputation and case-wise deletion were also used as an alternate to LOCF, given caveats therein (Mallinckrodt et al., 2003). As both yielded nearly identical results, only the LOCF analyses are included in this report.

Pearson product-moment correlations were used to determine the relationship between craving levels (as measured by QSU scores) and smoking behavior (as measured by average daily cigarette use over the prior week). Correlations were calculated at baseline, at the end of the 4-week treatment period, and at follow-up time-points.

Multiple regression analyses were used to assess the degree to which the independent variable of craving level (i.e. QSU score) predicted smoking behavior (i.e., average daily cigarette use) with measures of the amount of home practice also included as independent variables. To examine whether home practice predicted changes in the association between craving and smoking after four weeks of treatment, moderated regression analyses were also performed (Aiken and West, 1991). Specifically, we created an interaction term for each of the home practice measures and craving at the end of treatment. The main effects (home practice measures, craving scores) and the interaction between home practice and craving were then tested as independent variables predicting smoking, controlling for baseline levels of craving and smoking in the equation. All independent variables were mean centered to facilitate interpretation and reduce multicollinearity between main effects and the interaction terms.

Effect size was calculated utilizing Cohen's f^2 measure (Cohen, 1988). By convention, an f^2 of 0.02 is considered small, 0.15 is medium, and 0.35 is large. For moderation analyses, effect sizes of 0.02, 0.13, and 0.26 are considered small, medium and large respectively (Cohen et al., 2003). All tests of significance are reported as two-tailed.

3. RESULTS

3.1 Baseline demographics and clinical characteristics

Overall, as part of the clinical trial, 41 subjects were randomized to MT, 33 of which initiated treatment (see CONSORT diagram; Brewer et al., 2011). For more detailed information on subject characteristics, please see (Brewer et al., 2011). Briefly, chi-square and ANOVA analyses revealed no significant differences in baseline demographic characteristics between the individuals who started treatment and those who did not. Participants were on average 46 years old, 59% identified themselves as white, and 66% were men. On average, those who initiated treatment smoked 19 cigarettes/day, started smoking regularly at the age of 17, and had 6 previous quit attempts. Individuals who started MT attended 6.7 ± 1.7 of eight sessions, and practiced formal meditation practices an average of 5.4 day/week, and informal mindfulness practices an average of 5.6 days/week. Smoking, craving and home practice variables are summarized in Table 1.

3.2 Correlations between craving and cigarette use

We first examined the relationship between craving and smoking behavior using Pearson product-moment correlations at baseline, the end of treatment, and during follow-up interviews. We inspected scatter plots for wayward points, of which there were none. At the start of the 4-week treatment period, we found a strong positive correlation between self-reported craving and concurrent average daily cigarette use that week, i.e., those who reported higher levels of craving also smoked more cigarettes ($r = 0.582$, $p < 0.001$, Table 2). At the end of the 4-week treatment period, this correlation was reduced to the point of statistical non-significance ($r = 0.126$, $p = 0.491$). A test of equality of these correlation coefficients suggested that this was a non-random event ($z = 2.05$, $p = 0.04$). Importantly, craving scores at the end of treatment were about the same for individuals who quit smoking (2.18 ± 1.11) and those who did not (2.45 ± 1.53 ; Figure 2).

A positive correlation between craving and contemporaneous smoking reemerged at follow-up, two weeks after the end of treatment ($r = 0.47$, $p < 0.02$), and grew stronger both three ($r = 0.79$, $p < 0.001$) and four months after treatment initiation ($r = 0.77$, $p < 0.001$). This was due to increased spread in the craving scores among abstainers (smoking = 0) and non-abstainers (smoking > 0). In other words, people who were abstinent at the follow up time points reported lower levels of cravings (Mean range = 1.41–1.52), while those who continued to smoke, reported higher levels of craving (Mean range = 2.09 – 2.49) and

positive associations between craving and number of cigarettes smoked (Range $r = .31-.82$). Between-group differences in craving were significant at the 4 month follow up primary endpoint ($t_{(27)} = 2.26$, $p = 0.03$).

3.3 Craving and mindfulness home practice as predictors of cigarette use

As we had previously found that increased home practice is correlated with decreased cigarette use for both formal ($r = -0.44$, $p < 0.02$) and informal practice ($r = -0.48$, $p < 0.01$; Brewer et al., 2011), we next examined the relationship between craving and average daily cigarette use using linear regression. At baseline, craving predicted 33.9% of the variance in the average number of cigarettes smoked daily ($B = 3.449 \pm 0.88$, $p < 0.001$, $f^2 = 0.51$, Table 3). At the end of the 4-week treatment period, craving no longer predicted smoking ($B = 0.41 \pm 0.59$, $p = 0.491$, $f^2 = 0.016$). Change in craving (baseline – end of treatment) also did not predict smoking outcomes ($B = 0.29 \pm 0.48$, $p = 0.56$, $f^2 = 0.01$).

A moderator is a variable that alters the strength of a relationship between two variables (MacKinnon and Luecken, 2008). To examine whether mindfulness practice changed the association between craving and smoking over the course of treatment, we conducted moderated regression analyses with baseline levels of craving and smoking, craving at four weeks, and the interaction between craving and each form of mindfulness practice as predictors of average number of cigarettes per day at the end of treatment. MT home practice significantly predicted smoking, even when controlling for baseline craving and cigarette use. For example, a model that included number of days of formal practice per week as independent variables predicted 34.6% of the variance in average number of cigarettes smoked per day ($B = -1.21 \pm 0.41$, $p = 0.007$, $f^2 = 0.52$, Table 3). Thus, for every day of the week that individuals practiced, they smoked 1.2 fewer cigarettes. We observed the same relationship between home practice and craving for number of minutes of formal practice, days per week of informal practice, and number of times of informal practice (Table 3). Here, individuals smoked 0.009 fewer cigarettes for each minute of formal practice, 1.52 fewer cigarettes for each day/week of informal practice, and 0.033 fewer cigarettes for each time they performed an informal practice. Effect sizes for these models were large, ranging from 0.39 to 1.17 (Table 3).

As shown in Table 3, results from the moderated regression also indicated that days of informal practice significantly moderated the association between craving and smoking at the end of treatment ($B = 0.52 \pm 0.22$, $p = 0.03$, $f^2 = 1.17$). More home practice predicted a weaker association between craving and smoking. The other home practice variables did not significantly moderate the association between craving and smoking (Table 3).

4. DISCUSSION

The primary aim of this study was to identify potential moderating factors that were associated with the clinical effects of MT in reducing smoking. Results indicated that days of informal practice significantly moderated the association between craving and smoking at the end of treatment such that individuals who practiced more were smoking less, regardless of their level of craving. To the best of our knowledge, this is the first study to show that MT may decouple the positive correlation commonly seen between craving and smoking.

Interestingly, number of days of informal practice was the only measure of home mindfulness practice that significantly moderated the association between smoking and craving. The lack of statistical significance for the remaining home practice variables could be due to smaller effect sizes and our relatively small sample size. These findings could also be an indication that different types of mindfulness practice may be more or less important for changing different aspects of behavior and future research should continue to examine

whether the practice type (formal or informal), frequency (days/week) and/or amount (number of minutes or times) is particularly critical for behavioral change.

These data are directly in line with both non-human animal, and human models of addiction: behaviors are reinforced by both positive and negative reinforcement that feeds back to increase the salience of environmental cues and strengthen the associations between affective states and craving (Bevins and Palmatier, 2004). They are also supported by previous studies of substance use disorders showing that MT attenuates the relationship between negative affective states (depression) and alcohol craving, and that this moderates later substance use (Witkiewitz and Bowen, 2010). Further, they are in accord with previous observations that the positive relationship between high levels of craving and smoking is a linchpin in the addictive loop, which may be a critical target for long-term success in smoking cessation (Brewer et al., 2012). Importantly, the findings from this study also support the postulate that treatments that specifically target the relationship between craving and subsequent smoking can fundamentally change this relationship, leading to both healthier behavior for the individual, and additional benefits for the individual and society.

Our data may help to explain the discordant findings on craving and smoking that have been previously reported (Perkins, 2009). First, as shown by the associative learning models, both cues and affective states may lead to craving, which often can be complex and personal in nature (i.e., some affective or situational cues may be a strong trigger of craving for one individual but not for another). Also, classically-conditioned cues may contribute additional variance, which is also difficult to capture (Lazev et al., 1999). Further, as smoking behavior becomes more and more habituated, environmental cues may bypass conscious processes, such that smoking behavior may manifest in the absence of awareness of craving (Bargh and Chartrand, 1999; Curtin et al., 2006; Miller and Gold, 1994; Suhler and Churchland, 2009; Tiffany and Conklin, 2000). As such, capturing the variance that contributes to each of these factors and determining their relationship to smoking is challenging (Perkins, 2009). As suggested by this study, MT may capture a larger amount of variance in cue-, affect- and classically conditioned smoking than previous studies (54% with informal days/week), as it targets the downstream relationship between each of these and smoking behavior.

Additionally, as cue- and affect-induced craving do play a large role in smoking, a reduction in craving may be sufficient for concomitant decreases in smoking, but may not be necessary. A simplistic analogy is that craving is like a fire that is fed by smoking. When someone stops smoking, the fire of craving is still present and only burns down on its own once its fuel has been consumed (and no more fuel has been added). Our data provide direct support for this: (1) a drop in craving lags behind smoking cessation for individuals who quit, suggesting that at first there is residual “fuel” for craving to continue to arise, which then is consumed over time, leading to the observed delay in reduction in craving; and (2) craving continues for individuals who continue to smoke, suggesting that they continually fuel it (Figure 2). Importantly neither craving nor changes in craving predicted reductions in cigarette use immediately following MT.

These data may have clinical utility as they help to explain the dynamics of the craving/smoking relationship for individuals who are about to attempt quitting. Here, clinicians can inform patients what to expect when quitting, and more importantly, in simple terms explain the associative learning theory underlying *why* this may be the case, which in turn may improve outcomes (Lorig et al., 2001; Stewart, 1995). Also, whether through formal MT or informal clinician-patient interactions, our data suggest that by emphasizing the relationship between craving and smoking rather than trying to figure out ways to suppress or “get rid” of cravings, clinicians may help individuals be more successful in their quit attempts.

Through specifically targeting craving, our data suggest that MT may confer several advantages over standard cognitive therapy for addictions. First, instead of teaching a number of different techniques aimed at different components of the addictive loop (e.g., both avoidance of triggers and substitution of a more healthy behavior when craving arises, figure 1b), it teaches individuals to simply observe and ‘be with’ cravings, no matter what triggers them (cue or affect). As such, it may help people to learn one technique well, rather than dividing cognitive resources to learn several techniques (Brewer et al., 2011). MT may also be particularly beneficial for individuals in situations in which they are vulnerable to relapse, such as during strong affective states or when cognitively depleted (Muraven and Baumeister, 2000; Sayette, 2004), as mindfulness meditation has recently been shown to counteract self-control depletion in a laboratory setting (Friesen et al.). Comparing these laboratory-based probes between cognitive and mindfulness treatments in clinical populations may help to delineate the relative potential benefits of each of these treatments for particular patient populations, leading to improved individualization of treatment.

Strengths of this study include the use of a theory-based, hypothesis-driven design for analysis, and validated measures. This study has several limitations as well. First, it was of moderate size, which may have limited our ability to detect moderation effects of some home practices on the relationship between craving and smoking. Nonetheless, we still found significant effects of home practice in our primary analysis, and effects of moderation of informal home practice on the craving-smoking correlations. Future, larger studies that are sufficiently powered to detect effects of home practices that had smaller effect sizes are warranted. Second, daily home practice was only measured during treatment. Additional studies assessing daily practice after treatment completion will be important to determine the relationship between continued practice after treatment completion, craving and smoking behavior. Third, we did not have a control group that engaged in mindfulness home practice without receiving MT and thus we did not examine whether decoupling of the craving/smoking association that was moderated by home practice was specific to MT or whether the same associations would have been found in a non-MT group.

Fourth, though moderation analyses are designed to measure the effect of a moderator variable (in this case mindfulness home practice) on the relationship between two other variables (craving and smoking), it may only serve as a proxy for another, linked variable. Though we have previously shown that non-specific home practice in general does not account for the effects of MT (Brewer et al., 2011), thus controlling for time and other variables, there may have been other linked variables that were not captured, such as recent stressful events or mood within the MT group. Finally, the sampling of craving at each timepoint within a research setting may not accurately capture the strength and variability of craving that can fluctuate throughout the day, and can change depending on recentness of the last cigarette smoked. Future studies using experience sampling throughout the treatment period will help to control for these variables and to more specifically capture the effects of mindfulness vs. confounding variables as noted above in the third limitation (Berkman et al., 2011).

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Figure 1. Associative learning "addictive loop" for nicotine dependence

a) Smoking becomes associated with positive (green) and negative (red) affective states through positive and negative reinforcement. Cues that lead to these states (gray arrows) can also trigger cue-induced craving, and subsequent smoking, which becomes habitual after multiple rounds of reinforcement. b) Strategies that teach avoidance of cues or substitute behaviors may not directly dismantle the core addictive loop (black arrows). Avoidance of cues dampens input into the addictive loop, while substitute behaviors (blue arrows) circumvent the targeted addictive behavior (e.g. smoking). Copyright 2011 Judson Brewer. Reprinted with permission of author.

Figure 2. Decreases in craving scores lag behind abstinence with mindfulness training

Abstainers = individuals with biochemically-verified one-week point prevalence abstinence at the end of treatment and at their 4-month follow up interview. QSU = Questionnaire of Smoking Urges. * indicates a significant difference in craving scores at the 4-month primary endpoint, $p = 0.03$.

Table 1

Smoking, craving and mindfulness home practice.

Variable		Mean	SD
Smoking (cigarettes/day)	Baseline	18.85	± 8.83
	End of Treatment	4.13	± 4.31
Craving (QSU)	Baseline	3.96	± 1.49
	End of Treatment	2.31	± 1.33
Formal Home Practice	Total Minutes	342.08	± 226.36
	Days/week	5.44	± 1.77
Informal Home Practice	Days/week	5.60	± 2.07
	Total Times	107.30	± 78.87

Formal home practice included body scan, loving-kindness, and awareness of breath meditations. Informal home practice included setting daily aspirations, mindfulness of daily activities, and RAIN (Recognize, Accept, Investigate, Note). Craving measured by Questionnaire on Smoking Urges (QSU).

Table 2

Correlations between craving and cigarette use disappear after mindfulness training.

	Baseline (Week 0)	End of Treatment (Week 4)	6-Week Follow-Up	3-Month Follow-Up	4-Month Follow-Up
Craving (QSU) X Cigarette Use, Daily Average	r = 0.582 p < 0.001 N = 32	r = 0.126 p = 0.491 N = 32	r = 0.474 p = 0.020 N = 25	r = 0.788 p < 0.00001 N = 28	r = 0.768 p < 0.00001 N = 29

QSU = Questionnaire of Smoking Urges. Daily cigarette use is an average number of cigarettes smoked/day that week, as measured by the timeline follow-back method.

Table 3

Informal home practice moderates the relationship between craving and smoking.

<i>Time Point</i>	<i>Predictor Variable</i>	<i>r</i>	<i>R²</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>df</i>	<i>f²</i>
Baseline (Week 0)	Overall Model	0.582	0.339			<0.0001	1, 31	0.51
	Craving			3.45	±0.88	<0.0001		
End of Treatment (Week 4)	Overall Model	0.588	0.346			0.040	5, 26	0.52
	Baseline Craving			0.061	±0.579	0.918		
	Baseline Cigarette Use			-0.56	±0.099	0.574		
	End of Treatment Craving			0.255	±0.594	0.672		
	Formal practice (days/week)			-1.208	±0.412	0.007		
	Craving*Formal practice			0.487	±0.558	0.391		
	Overall Model	0.529	0.280			0.108	5, 26	0.39
	Baseline Craving			-0.091	±0.608	0.882		
	Baseline Cigarette Use			-0.085	±0.102	0.414		
	End of Treatment Craving			0.290	±0.589	0.627		
	Formal practice (minutes)			-0.009	±0.004	0.018		
	Craving*Formal practice			-0.003	±0.005	0.533		
	Overall Model	0.735	0.540			0.001	5, 26	1.17
	Baseline Craving			0.266	±0.489	0.591		
	Baseline Cigarette Use			-0.053	±0.083	0.53		
	End of Treatment Craving			0.208	±0.455	0.652		
	Informal practice (days/week)			-1.522	±0.311	< 0.0001		
	Craving*Informal practice			0.515	±0.219	0.026		
	Overall Model	0.615	0.378			0.023	5, 26	0.61
	Baseline Craving			0.609	±0.595	0.315		
	Baseline Cigarette Use			-0.097	±0.095	0.315		
	End of Treatment Craving			0.289	±0.537	0.595		
	Informal practice (times)			-0.033	±0.010	0.002		
	Craving*Informal practice			0.009	±0.006	0.170		

Regression analyses that include craving (baseline and end of treatment) and home practice (formal and informal) as independent variables predicting the average number of daily cigarettes smoked the last week of treatment. B = unstandardized regression coefficient, df = degrees of freedom, η^2 = effect size.