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Craving And Quitting: An Exploration Of How Mindfulness Training May Help Smokers To Quit

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Abstract

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Cigarette smoking is the leading cause of preventable deaths in the world. A majority of smokers identify tobacco as harmful and express a desire to quit. Currently available treatments have shown only modest success, and abstinence rates remain low. Mindfulness Training (MT) shows promise as an effective treatment for smoking cessation, yet the mechanisms remain unclear. Craving has been shown to be a central component of the addictive process, and a strong predictor of smoking. MT is theorized to work by dismantling this addictive process by targeting craving. The purpose of this report was to examine the effects of MT on the relationship between cigarette craving and smoking. We hypothesized that MT would work to weaken the relationship between craving and subsequent smoking, and that this diminution would be directly related to the amount of home practice that individuals performed.

33 adults received MT as part of a randomized controlled trial for smoking cessation, each of whom recorded home practice details in daily diaries. Analyses showed that strong positive correlations between craving and smoking at baseline (r = 0.582) disappeared by the end of the treatment period (r = 0.126). Multiple regression models revealed home practice as a significant predictor of cigarette use (formal: R^2=0.315, p=0.004; informal: R^2=0.437, p<0.001). Furthermore, regression analyses revealed that the amount of informal home practice as measured in days/week moderated the relationship between craving and smoking such that individuals were smoking less regardless of their level of craving. These findings suggest that MT decouples the relationship between smoking and craving, and also show a direct link between theoretical mechanisms of mindfulness and behavior.

Acknowledgements:

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Introduction

In the US, tobacco use accounts for an estimated 443,000 premature deaths, or one out of every five deaths, every year [1,2]. For every one American who dies from smoking, another twenty suffer from at least one serious smoking-related disease [2]. These chronic diseases associated with smoking are estimated to cost society $193 billion in lost productivity and healthcare costs annually [1].

Despite being deluged with data regarding the dangers of smoking, tens of millions of Americans continue to smoke daily [3,4]. Yet, the majority of these smokers identify tobacco as harmful and express a desire quit: a 2010 report from the CDC indicated that approximately 70% of current smokers want to quit [5]. In fact, about 50% of smokers had tried to quit smoking during the past year, yet the prevalence of recent cessation was only 6.2% [5]. Perhaps even more troubling is the fact that some smokers appear to simply stop trying to quit as they get older; quit attempts were reported by 62.4% of those aged 18 – 24 years old, compared with 43.5% of those older than 65 years old [5].

Nicotine is addictive

Every year a significant portion of the millions of people who try to quit smoking fail within the initial few days or weeks of the cessation effort [6]. Among those who attempt quitting without formal treatment, only 3-5% remain abstinent for 6-12 months [7]. Even among those who do receive treatment, over 60% resume smoking within 30 days of quitting, and almost 90% resume within a year of quitting [8]. Data from the National Comorbidity Survey showed that about 30% of people who have ever tried

smoking become daily smokers; the comparable statistics for heroin, cocaine, and alcohol were 23%, 17%, and 15%, respectively [9].

Clearly cigarettes and other forms of tobacco products are addictive, and of the over 4000 chemicals found in cigarettes there is little debate in the scientific community that nicotine is the primary addictive compound found therein [2]. A number of factors contribute to nicotine's ability to cause such strong addiction. These include: neuro-adaptations that occur with chronic intake of nicotine, known as tolerance; the withdrawal symptoms that most experience upon discontinuation of nicotine intake; and, the effects of nicotine that reinforce dependence [2].

Tolerance may be understood as reduced responsiveness to a given concentration of a drug as a consequence of earlier exposure to that drug [10]. There is ample evidence that, compared to non-smokers, smokers exhibit tolerance to the subjective effects of nicotine such as "head rush" and nausea [11]. Despite the fact that tolerance appears to be associated with long-term smokers, debate remains as to whether it is a consistent marker of nicotine dependence [12]. It is during the onset of dependence that tolerance to higher doses of nicotine may be of more importance. It is during this critical time that the development of acute tolerance to the aversive affects of nicotine must occur to facilitate the likelihood of escalation from a couple of cigarettes per week to a pack per day or more [13].

In those already dependent on nicotine, the distressing symptoms of withdrawal are a predictable consequence of abstaining from smoking. This includes, but is not limited to, restlessness, increased appetite, sleep disturbance, lability, irritability, anger, anxiety, depression, and difficulty concentrating, [7] [14]. However, craving is potentially the most important feature of nicotine withdrawal [15]. It is one of the main reasons cited

for relapses and lapses, and is often so feared by smokers that they don't even attempt to quit despite a desire to. Addressing withdrawal symptoms and the consequent craving or urge to smoke is a primary treatment strategy to maintain smoking cessation.

Nicotine appears to have a number of behaviorally reinforcing effects that contribute to both the onset and maintenance of dependence. A stimulus may be considered reinforcing if it increases a response or behavior resulting in obtaining that stimulus. As such, the most commonly used index of reinforcement in smoking and nicotine addiction research is the number of cigarettes smoked per day, or smoking frequency, and typically assessed by self-report. The reinforcing effects of nicotine may be either positive or negative, such as rewarding psychoactive effects of nicotine and/or the alleviation of aversive states (such as relief from withdrawal symptoms). Other reinforcing effects of nicotine include the modulation of negative affect (such as reducing anxiety, sadness, or fatigue) [16], enhancing the ability to maintain attention and concentration during cognitively demanding tasks [17], and blunting appetite and maintaining lower body weight [18].

Addiction Model

Just as important as the primary effects of nicotine on neural functioning are the associative processes that develop with repeated tobacco use [19]. The acquisition and maintenance of nicotine dependence is a complex process, one that is developed by associative learning mechanisms and perpetuated by both positive and negative reinforcement [20] [21] [22]. Associative memories are often formed between smoking and both positive and negative affective states, such as after a good meal or after an argument

with a friend, respectively (Figure 1). If smoking leads to maintenance of the positive affect, or decreases the negative affect, an associative memory is formed between the two. Brewer 2010 [23] [24] [25] [26]. Going forward, cues that trigger these affective states may then become associated with smoking, and subsequently induce craving for a cigarette [27] [21]. Over time and with repetitive smoking, responding to these cues may become an automated process which leads to cue-induced behaviors that lay outside of conscious control [27] [28] [29]. 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.

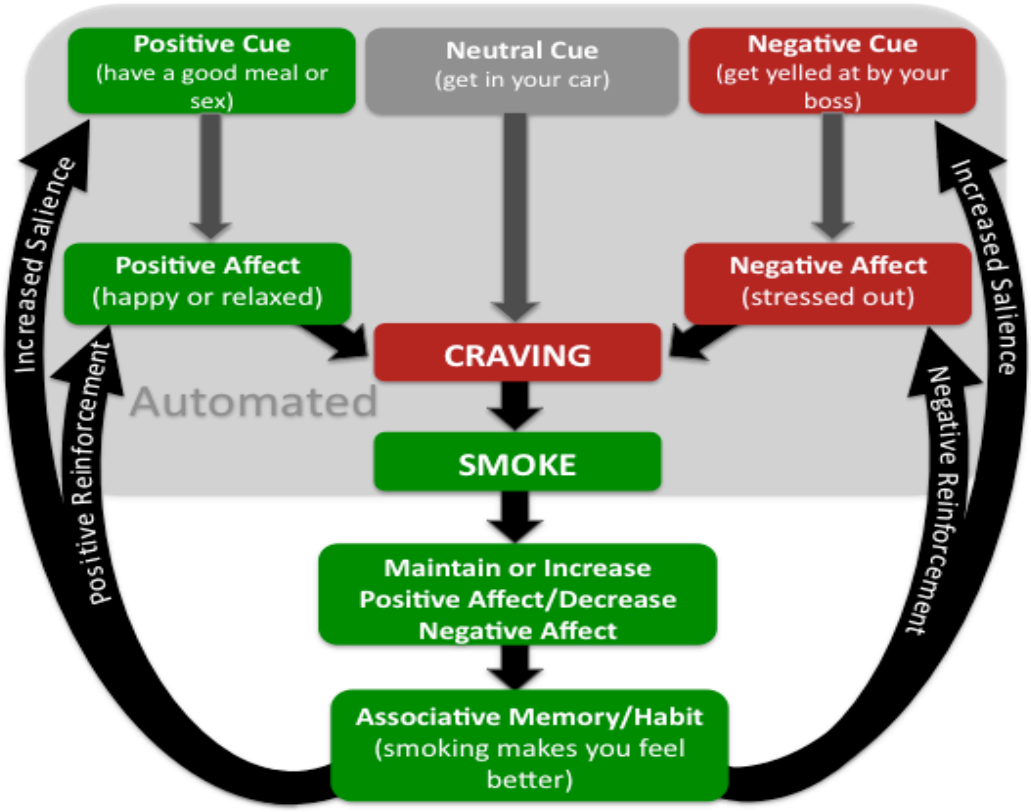


Figure 1. **Associative learning "addictive loop" for nicotine dependence**.
Smoking becomes associated with positive (green) and negative (red) affect through positive and negative reinforcement. Cues that trigger these states (gray arrows) lead to cue-induced craving, furthering this process, which through repetition becomes automated over time. Strategies that teach avoidance of cues or substitute behaviors do not directly dismantle the core addictive loop

(black arrows), leaving individuals vulnerable to relapse to smoking. Copyright 2011 Judson Brewer. Reprinted with permission of author.

Craving

Robinson and Berridge eloquently expressed a basic view held by many addiction scientists [30]:

> "To understand addiction, therefore, we need to understand the process by which drug-taking behavior evolves into compulsive drug-taking behavior. Presumably, this transformation in behavior occurs because addicts develop an obsessive craving for drugs, a craving that is so irresistible that it almost inevitably leads to drug seeking and drug taking" (p. 247).

Craving is unpleasant, and smoking is often motivated by a desire to reduce it. Individuals who smoke tend to avoid places where they know they cannot smoke, and if this is not possible they will often become anxious and eager to go to where they can smoke. Daily schedules are often planned with smoke breaks in mind. Smokers who, for whatever reason, do not have cigarettes can become so desperate that they will approach a complete stranger to ask for a cigarette. The longer that craving remains unsatisfied, the more intense it may become [31].

Craving and subsequent smoking behavior have long been closely associated amongst daily smokers [20,32-35]. Adults who report higher levels of craving also exhibit higher levels of daily cigarette consumption [36], a relationship that has also been demonstrated in adolescent smokers [37 38].

West and Schneider define craving as "feelings of need for a cigarette" [15]. Some addiction scientists separate craving by drawing a distinction between desire and intent. This distinction is noted because, although they are strongly coupled in active smokers (who, as mentioned, will actively work to overcome obstacles to smoking), the two may become uncoupled from one another in those who are trying to quit or are in situations where smoking is not possible [32,39].

The intensity of craving experienced by a smoker, or any addict for that matter, is influenced by two independent, fluctuating factors: (a) the duration of abstinence since last use, and (b) the presence of external cues and affective states that have already attained incentive-motivation significance due to prior associative learning (Figure 1) [33 40]. In smokers, abstinence-induced (i.e. background) craving increases in intensity to a peak one to two days after quitting and then declines over a number of days or weeks with continued abstinence [40]. On the other hand, cue- or affect-induced craving can arise within moments upon exposure to cues or triggers [41], and may even continue to arise years after quitting [32,42].

Craving is potentially the most important feature of cigarette withdrawal, in that it is often the most difficult obstacle to overcome for smokers attempting to quit [15 34]. Intense and unremitting craving often precedes the initial lapse following a cessation attempt, and it is estimated that about 90% of smokers who lapse will progress to have another lapse often within the same day [43]. In fact, a number of studies have shown that increases in the intensity of craving can accurately predict lapse and relapse risk [33,34,44]. For example, in a study of treatment-seeking smokers, for each standard deviation increase in craving scores on the target quit date, the risk of lapsing rose by 43% on that day, and 65% on the following day [45]. In a study of women smokers who provided daily

reports of craving during a 30 day period prior to relapse, craving scores increased by 1.4 standard deviations 4-5 days before, and peaked on the day of relapse [46].

Limitations of currently available treatments

The sheer number of cues that smokers can associate with positive and negative affective states, in addition to neutral states, greatly complicates quit attempts by presenting a veritable minefield of opportunities for relapse. Current pharmacotherapies such as nicotine patch, bupropion, or varenicline, have been unable to prevent cue-induced craving, focused instead on the reduction of background craving and other symptoms of nicotine withdrawal [47] [48] [49] [50]. Only nicotine gum has demonstrated efficacy in providing momentary relief from cue-induced craving [51]. However, this is a substitution strategy that does not effectively target affective states that can themselves induce craving, leaving the aforementioned addictive loop intact.

In addition, most of the current behavioral treatments for smoking cessation also leave the addiction loop intact (Figure 2). This may be because they focus on teaching individuals to avoid cues and to divert their attention away from cravings, to substitute other activities for smoking, or to promote positive affective states by practicing relaxation or exercising [52] [53]. These treatments have shown only modest success, as abstinence rates in the US have remained under 30% for the past 30 years [52]. 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 [54] [50], and

substitutions are not always available or effective. As a result, although it may become dormant, the addictive loop remains intact and prone to reactivation (Figure 2).

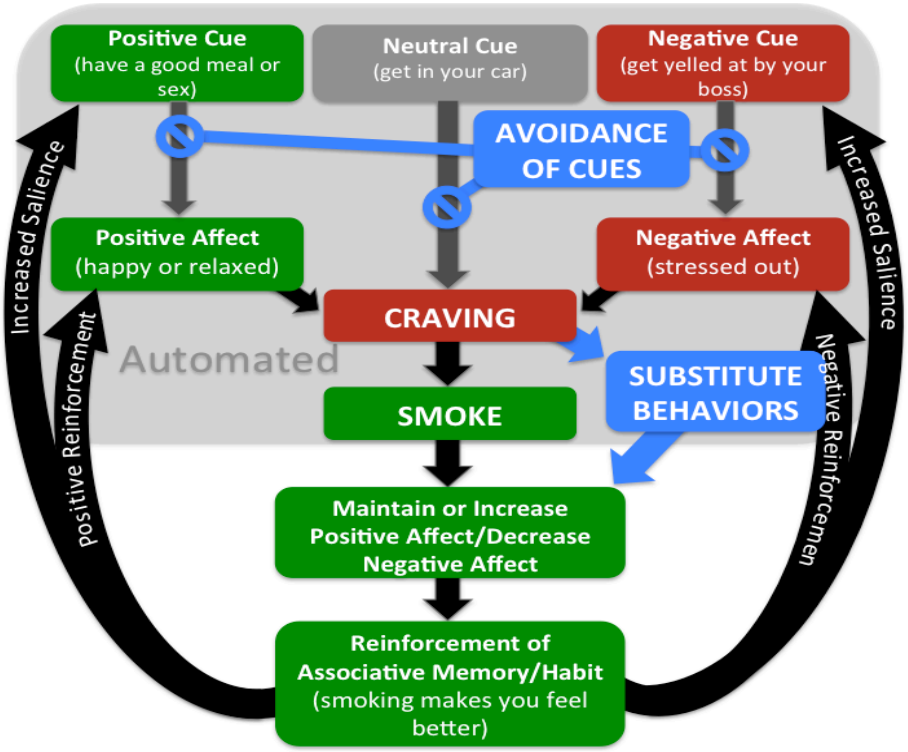


Figure 2. Limitation of current treatment paradigms in dismantling the addictive loop: avoidance of cues dampens input into the addictive loop (black arrows). While substitute behaviors (blue arrows) circumvent the targeted addictive behavior (e.g. smoking). However, neither of these strategies dismantles the addictive loop at its core. Copyright 2011 Judson Brewer. Reprinted with permission of author.

The evidence for the central role of craving in addiction, coupled with the shortcomings of current treatments, highlights the need for new approaches [55] [31]. The efficacy of any new approach will hinge on its ability to directly target and dismantle the core links of the addictive loop. Recent evidence suggests that treatments such as Mindfulness Training may do exactly that [56] [22] [31].

Mindfulness Training, Treatment of Addictions

Mindfulness may be described as an awareness of moment-by-moment experience arising from attention that is characterized by curiosity toward and acceptance of these present-moment experiences [57] [58]. Mindfulness Training (MT) is derived from Buddhist practices, and adapted for use in Western cultures under a number of different forms: Mindfulness-based Stress Reduction, Mindfulness-based Cognitive Therapy, and Mindfulness-based Relapse Prevention [59] [60] [61,62]. Mindfulness training has been explored as a treatment for pain [59] [63], anxiety disorders [64] [65] [66], and depression [61] among others.

More recently, Mindfulness Training has been evaluated as a treatment for addictions [67] [62] [68] and specifically smoking [56,69] [22]. Evidence for the efficacy of MT in treating addictions remains preliminary, however. In a recent review of trials that included mindfulness-based interventions Zgierska et al found that, despite a range of promising results, very few of the already limited number of clinical trials conducted prior to 2009 were randomized [70]. Since 2009, several randomized clinical trials have shown promising results. Brewer and colleagues conducted a pilot study of cocaine and alcohol dependence and found that after eight weeks of treatment MT had equivalent efficacy to Cognitive-Based Therapy, the current 'gold-standard' treatment for addictions [68]. In addition, they found that after treatment the subjects who received MT showed adaptive physiologic and autonomic changes during a laboratory-based stress challenge that were not observed in the CBT group. In another randomized pilot trial Bowen and colleagues found that, compared to those receiving treatment as usual,

subjects who received Mindfulness-Based Relapse Prevention showed significantly lower rates of substance use up to four months post-intervention [62].

Mindfulness Training has also provided reason for optimism regarding its efficacy as a treatment for smoking cessation. After an uncontrolled trial Davis and colleagues reported that 10 of 18 participants who had received MT were abstinent six weeks after quitting [69]. In another trial Bowen et al found that after providing brief mindfulness-based instructions (to accept thoughts non-judgmentally, and to pay attention to urges and accompanying sensations without trying to change or get rid of them) to college students, they smoked significantly fewer cigarettes seven days post-intervention compared to those students who did not receive the instructions [56]. Interestingly, this result 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 (a cognitive behavioral therapy based treatment endorsed by the American Lung Association) as stand-alone treatments for smoking cessation [22]. Compared to participants who received FFS, those who received MT showed a greater rate of reduction in cigarette use during treatment and maintained these gains during follow-up (F = 11.11, p = .001). They also showed a trend towards greater point prevalence abstinence rate at the end of treatment (36% vs 15%, p = .063), which was significant at the 17-week follow-up (31% vs 6%, p = .012) [22].

These promising results indicate that Mindfulness Training may be more effective than current gold-standard behavioral treatments for smoking cessations.

However, the psychological mechanisms behind the efficacy of MT remain unknown. How does MT help cigarette smokers to quit?

Mindfulness Training May Directly Target the Addictive Loop

In teaching the simple concepts of paying attention to and accepting momentary experience, MT broadly targets different links of the addictive loop, and craving in particular [71]. By learning to pay attention individuals may be able to 'de-automate' habits linked to minimally conscious affective states and sensations [63 72 31]. By observing and non-judgmentally accepting uncomfortable mind- and body-states rather than reacting to them, MT may help individuals to replace stress-induced habitual reactions with more adaptive responses [21,31].

By helping people change their relationship to negative affect and physically unpleasant states (e.g. craving) and thoughts, MT may bolster their ability to 'ride out' cravings and subsequently quit smoking or other addictions [31,56,72]. Smokers may learn to bring mindful awareness to the sensations and thoughts that accompany a craving, and just observe rather than immediately react to it. This awareness can lead to two important insights. First, by stepping back and exploring what cravings actually feel like in their body, an individual may learn that they are physical sensations and not something they have to get rid of immediately. Second, each time she rides-out a craving an individual may learn that they are not permanent and will subside even if unsatisfied. Cravings may continue to arise, but by learning to observe and not

immediately react to them, an individual can begin to disrupt the associative learning process and dismantle the addictive loop (Figure 3) [31].

Rather than focusing on the removal of stimuli that might propagate the addictive loop, as with current behavioral treatments, Mindfulness training over time may lead to the dismantling of the associative learning process of smoking.

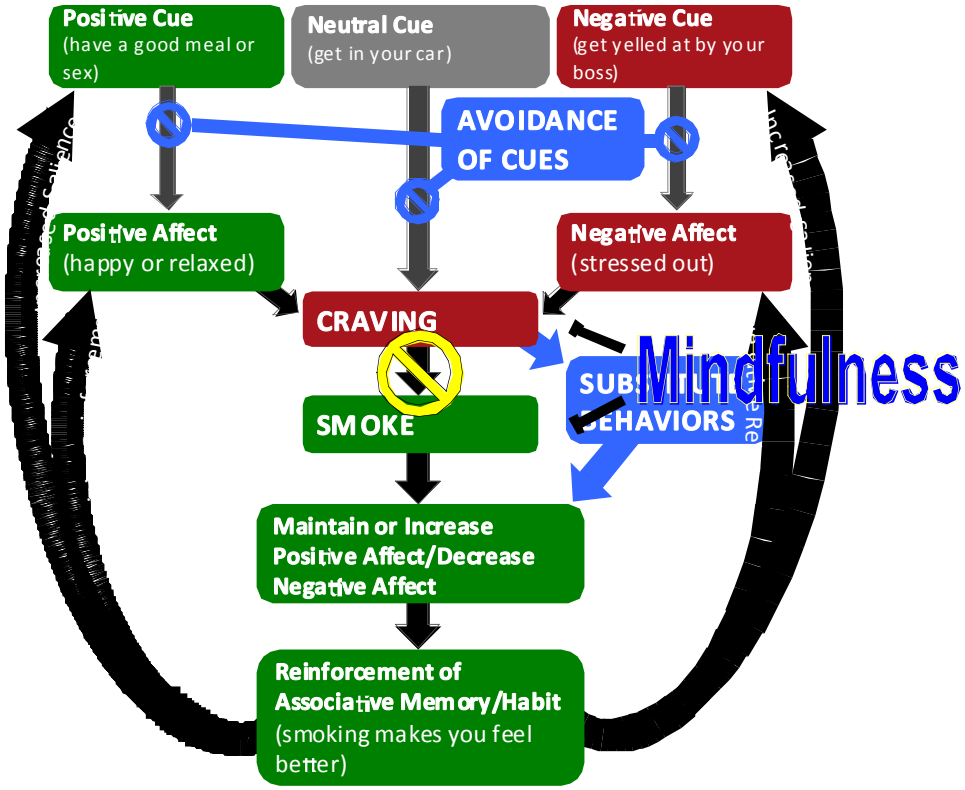


Figure 3: Mindfulness Training targets specific links in the addictive loop, and may help to dismantle it over time. Copyright 2011 Judson Brewer. Reprinted with permission of author.

The mechanistic underpinnings of MT remain unclear. In order to better understand whether decoupling the associative connection between craving and smoking is indeed how MT may help smokers to quit, in the current study we examined

this relationship between craving and smoking behavior, as well as other factors that might influence this relationship. If craving is central to the addictive loop and strengthens the associative learning process that drives it, while MT theoretically dismantles this loop, one might wonder whether MT lessens the strength of the relationship between craving and subsequent smoking behavior. In this report, we evaluated the relationship between cigarette craving and cigarette use before and after individuals received MT for smoking cessation. The primary objective was to determine how the relationship between craving and smoking changed with treatment, and if/how it was affected by MT, as measured by the amount of formal and informal home practice that was performed. The secondary objective was to determine if home practice moderated this relationship. In accord with its theorized mechanism of action, we hypothesized that individuals would demonstrate a strong correlation between craving and smoking before treatment, and that this would diminish with MT. We also 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.

Methods

(Note: this author was not directly involved in recruiting subjects, randomization, treatment delivery, or follow-up assessments. These were conducted by Brewer and colleagues as part of the original study [22]. This author was responsible for the subsequent statistical analyses not presented in the original paper.)

Study Design and Objective

This analysis examined data originally collected by Brewer and colleagues during a clinical trial evaluating the efficacy of Mindfulness Training for smoking cessation [22]. The study was a randomized, controlled trial with a 4-week treatment period, and post-treatment follow-up interviews at 6, 12, and 17 weeks after treatment initiation. Their protocol was approved by the Yale University and Veteran's Administration institutional review boards.

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.

Of the 103 eligible individuals, 88 were randomly assigned to receive either Mindfulness Training (MT) or the American Lung Association's Freedom from Smoking (FFS) treatment. Participants were urn randomized to either treatment group based on age, sex, race, and cigarettes smoked per day.

Interventions:

Both MT and FFS treatments were delivered in a group format twice weekly over 4 weeks, for a total of 8 sessions. Sessions were manualized and delivered by instructors experienced in MT or certified in FFS, respectively. Both MT and FFS had a quit date at the end of week 2 (session four), were matched for length (1.5 h/session) and delivered on the same days of the week (Monday and Thursday). In addition, home practice materials were matched in a number of ways, including the length (~30 min total) and number of tracks (five) on respective CDs.

FFS served as the 'standard treatment' control condition namely because it is a validated and widely disseminated 'gold-standard' treatment for smoking cessation [53 73]. Furthermore, it is manualized, and standards for training and certification of therapists are established [74]. FFS includes components that are well-matched with MT, but does not include the hypothesized mechanism of MT as it focuses on avoidance rather than acceptance of triggers, and substitution strategies instead of awareness of cravings when

they arise [22]. Briefly, the program covered behavior modification, stress reduction, and relapse prevention, and was divided into three stages: preparation, action, and maintenance. In the preparation stage (sessions 1–3), participants examined smoking patterns through self-monitoring, identified triggers, and developed a personalized quit plan. On quit day (session 4), participants affirmed their decision to quit and identified specific coping strategies. During the maintenance stage, participants identified ways to remain smoke-free and maintain a healthy lifestyle (e.g., weight management, exercise, and relapse prevention), and continued to discuss the importance of social support and relaxation strategies. Home practice was suggested after each session typically as a combination of formal (e.g., practicing guided relaxation techniques) and informal (e.g., "packtracks") techniques. Each participant received a practice CD of cessation techniques.

Mindfulness Training was adapted for smoking cessation from a previous MT manual for drug relapse prevention [62,68]. The main themes of awareness of the moment, and acceptance of cravings and affect, were introduced and reinforced throughout the training [59]. The first session introduced participants to the concept of how smoking can become a habituated behavior triggered by an environmental, physical, or mental stimulus through associative learning. It also explored how cravings feel in the body and how MT can help individuals become more aware of these processes. Session two examined how thoughts, emotions and body sensations become triggers for craving and smoking, and introduced a technique to 'mindfully' work with cravings (Recognize, Accept, Investigate and Note what cravings feel like as they arise, acronym: RAIN). Session three introduced how difficult emotions perpetuate smoking as well as a standard meditation technique called loving-kindness as a way to work with them [75].

Loving-kindness is practiced through directed well-wishing, typically by repetition of phrases such as 'may X be happy'. Session four (quit date) taught participants how cravings thwart long-term goals, and reinforced mindfulness techniques as a way to help individuals disengage from habitual responding and realign with their goals. Session five introduced participants to mindfulness practice in everyday life, including "awareness of breath" meditation and mindful. Session six explored the automaticity of thought, and how thoughts can lead to habitual behaviors. Session seven reinforced the concept of acceptance and its role in changing habits. It also explored how both mental and physical actions can "plant seeds" for future actions and habits. Session eight summarized the course tools and explored ways of maintaining these in the future [22].

Home practice was suggested after each of the 8 sessions as a combination of formal and informal MT meditations [22]. 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 others, usually by repeating a phrase such as 'may X be happy,' 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 (RAIN: Recognize, Accept, Investigate, and Note) and difficult emotions (SOBER: Stop, Observe, Breathe, Expand awareness, Respond with full awareness). 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. Each participant received a meditation practice CD.

Post-Treatment Follow-Up Assessment

Participants in both groups were requested to return for follow-up interviews at 6, 12, and 17 weeks post-treatment initiation. Each of these follow-up interviews assessed smoking status, craving levels, and information regarding amount and type of home practice. Participants were instructed to provide general summaries of their home practice since the end of treatment or previous follow-up visit. This home practice data was not used in the current analysis due to inconsistencies in the home practice journals.

Study Data Points

Craving levels and smoking status were assessed at baseline, at the end of treatment, and at follow-up interviews at 6, 12, and 17 weeks post-treatment initiation. 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.

Smoking Status

Subjects were instructed to report the number of cigarettes they smoked each day as part of their structured daily diaries. These were checked twice weekly at in-person visits by a research assistant who was not involved in treatment delivery. Subjects who reported continued smoking were assessed by the timeline follow back method (TLFB) [76] [77]. Each verification check included exhaled carbon monoxide measurements. Reported abstinence was verified by an exhaled carbon monoxide measurement of ≤ 10 parts per million as previously described [22].

Craving

Subjective craving was assessed using the Questionnaire of Smoking Urges – Brief (QSU-B) [78] [79]. 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"). Factor analyses by Cox et al., and confirmed by Toll et al., found that this self-reported measure of craving results not only in a total score but also reflects a two-factor structure. Factor 1 items represent a strong desire and intention to smoke, while Factor 2 items reflect an anticipation of relief from negative affect with an urgent desire to smoke [79] [80].

Statistical Analysis

Longitudinal data were analyzed using intent-to-treat models on the full sample of randomized subjects. Demographics and baseline clinical characteristics were examined using ANOVA and χ^2 analysis, using SPSS 19. All tests of significance are reported as two-tailed, and error is reported as ± standard deviation. 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. LOCF is an approach specific to longitudinal designs and is used regularly in clinical trials [81,82] [83]. Multiple imputation and case-wise deletion were also used as an alternate, given the caveats of LOCF [84]. As they yielded nearly identical results, only the LOCF analyses are included in this report.

Pearson Product Moment correlations were used to determine the relationship between smoking behavior (as measured by average daily cigarette use over the prior week) and craving levels (as measured by QSU scores). Correlations were calculated at baseline, at the end of the 4-week treatment period, and at follow-up (6, 12, 17-weeks from treatment initiation).

Multiple regression analyses was 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. The equation can be written conceptually as "AvgCigUse ≈ (W1) Craving + (W2) Home Practice," where W1 and W2 represent weighting factors measuring relative importance in the equation. This can be rewritten mathematically as "$Y = A + B_1X_1 + B_2X_2$." In terms of output we report r^2 values as a measure of the strength of the association, i.e. a reflection of the percentage of the variation seen in cigarette use that can be explained by the independent variables. Effect size was calculated utilizing Cohen's f^2 measure:

$$f^2 = r^2 / (1 - r^2)$$

where r^2 is the squared multiple correlation. By convention, f^2 effect sizes of 0.02, 0.15, and 0.35 are termed small, medium, or large [85].

Moderated regression analysis was performed *post-hoc* to assess the possibility that the amount of home practice done by a MT participant might have moderated the relationship between craving and smoking frequency after 4 weeks of MT treatment. As described by Baron and Kenny as well as others, a moderator is a variable that alters the strength or direction of the relationship between a predictor and an outcome variable [86] [87] [88]. In other words, the impact that an independent variable has on a dependent outcome variable varies according to the level or value of the moderator [89]. In this case, the hypothesis was that the impact craving had on subsequent smoking behavior was altered by the amount of home practice that subjects reported.

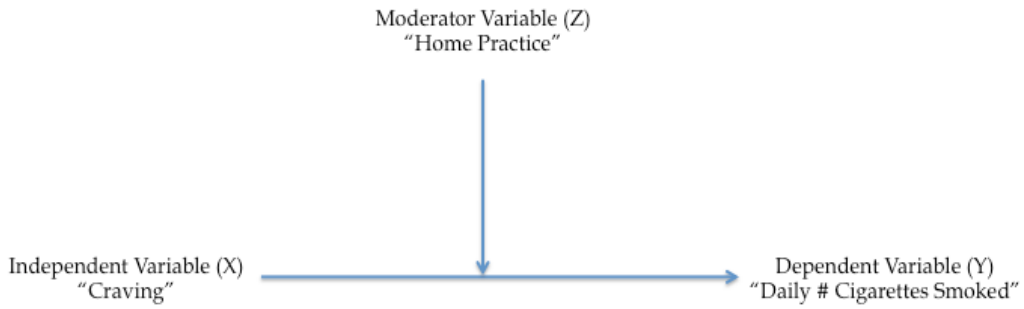


Figure 4: Diagram of Moderator Effect

Multiple regression techniques may be utilized to examine the effect a moderator variable has on the predictor of an outcome variable. The moderated regression equation includes the independent predictor variable, the moderator variable, and an interaction term that is the represented by the product of the predictor and moderator [86,90] [89]. When two predictors in regression analysis interact with one another, the regression of the dependent variable on one of those predictors depends, or is conditional, on the value of the other predictor. The moderated regression equation takes the form:

$$Y = A + B_1X_1 + B_2X_2 + B_3(X_1*X_2)$$

In this equation, the regression coefficients for X_1 and X_2 reflect conditional relationships. For example, B_1 is the effect of X_1 on Y when $X_2 = 0$.

$$Y = A + B_1X_1 + B_2X_2 + B_3(X_1*X_2)$$
$$= A + B_1X_1 + B_2(0) + B_3(X_1*0)$$
$$= A + B_1X_1$$

So, we can say that for a subject who reports home practice (X_2) = 0 minutes, a 1 unit increase in craving score (X_1) will produce, on average, a B_1 increase in number of cigarettes smoked (Y).

However, if a subject reports home practice = 100 minutes over the treatment period, the effect of craving on smoking behavior will be:

$$Y = A + B_1X_1 + B_2X_2 + B_3(X_1*X_2)$$
$$= A + B_1X_1 + B_2*(100) + B_3(X_1*100)$$
$$= A + B_1X_1 + 100B_2 + 100B_3X_1$$
$$= A + 100B_2 + (B_1 + 100B_3)X_1$$

Thus, a one unit increase in craving (X_1) will produce a (B_1 + $100B_3$) unit increase/decrease (depending on the sign of the coefficient) in the number of cigarettes smoked daily (Y).

Basically, this means that if one asks the question, "What is the effect of craving level on the number of cigarettes smoked in a day?," the answer may be "It depends on how much home practice they've done," i.e. what X_2 equals. This response would be correct if the amount of home practice indeed moderates the relationship between craving and smoking behavior. To test this hypothesis, moderated regression was performed in the style described by Aiken and West [90], with craving level as the predictor variable, amount of home practice as the moderator variable, and an interaction term between the predictor and moderator (= craving x practice). All independent variables were mean centered to facilitate the interpretation of conditional effects and reduce multicollinearity between main effects and the interaction terms [90].

Cohen's f2 was utilized to calculate the effect size, using the equation:

$$f^2 = [\ (r^2)_{AI} - (r^2)_A\ ]\ /\ [\ 1 - (r^2)_{AI}\ ]$$

where $(r^2)_{AI}$ is the squared multiple correlation resulting from the full regression model containing the interaction term, and $(r^2)_A$ is the squared multiple correlation resulting from the original regression model without the interaction term. Cohen's f^2 gives the proportion of systematic variance accounted for by the interaction relative to the unexplained variance in the criterion. Conventions determined by Cohen: $f^2 = 0.02$ is a small effect, $f^2 = 0.15$ is a medium effect, and $f^2 = 0.26$ is a large effect [91].

Results

Baseline Demographics and Clinical Characteristics

Of the 88 randomized subjects, 41 were randomized to the Mindfulness Treatment group, 32 of which initiated treatment. 47 subjects were randomized to the Freedom from Smoking group, and 38 initiated treatment. (Following the randomization one individual was excluded from the FFS group after being incarcerated, and his data were not analyzed per Veteran's Administration regulation.) X^2 and ANOVA analyses revealed no significant differences in baseline demographic characteristics between the individuals who started treatment and those who did not.

Overall, participants were 46 years old, 55% identified themselves as white, and 63% were men. On average they smoked 20 cigarettes/day, started smoking regularly at the age of 16, and had 5.2 previous quit attempts. (See Table 1)

Individuals in MT who started treatment (n=32) attended 6.7 ± 1.7 of eight sessions. The 6, 12, and 17-week follow-up completion rates were 27 (82% of treatment-exposed individuals), 33 (100%), and 29 (88%), respectively. FFS subjects who initiated treatment (n=38) attended 6.2 ± 2.2 of eight sessions and had 6, 12, and 17-week follow-up completion rates of 32 (84% of treatment-exposed individuals), 29 (76%), and 33 (87%), respectively. No serious adverse events were reported in either group.

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	**Total, N=87** N (%)	**MT, N=41** N (%)	**FFS, N=46** N (%)	*F* or X^2	df	*p*
Sex				.472	1	.492
Male	54 (62.1)	27 (65.9)	27 (58.7)			
Female	33 (37.9)	14 (34.1)	19 (41.3)			
Race				4.557	3	.207
White	43 (49.4)	24 (58.5)	19 (41.3)			
Black	34 (39.1)	15 (36.6)	19 (41.3)			
Hispanic	9 (10.3)	2 (4.9)	7 (15.2)			
Other	1 (1.1)	0 (0.0)	1 (2.2)			
Education level				1.715	3	.634
College grad or more	25 (28.7)	12 (29.3)	13 (28.3)			
Partial college	25 (28.7)	10 (24.4)	15 (32.6)			
High School	31 (35.6)	17 (41.5)	14 (30.4)			
Less than high school	6 (6.9)	2 (4.9)	4 (8.7)			
Marital Status				.376	3	.945
Never married	45 (51.7)	20 (48.8)	25 (54.3)			
Married/Cohabitating	15 (17.2)	8 (19.5)	7 (15.2)			
Separated/Divorced	25 (28.7)	12 (29.3)	13 (28.3)			
Widowed	2 (2.3)	1 (2.4)	1 (2.2)			
Employment Status				.899	2	.638
Full time	28 (32.2)	15 (36.6)	13 (28.3)			
Part time	13 (14.9)	5 (12.2)	8 (17.4)			
Unemployed	46 (52.9)	21 (51.2)	25 (54.3)			
Continuous Variables	**mean (±SD)**	**mean (±SD)**	**mean (±SD)**			
Age	45.9 ± 10.2	46.5 ± 8.7	45.3 ± 11.4	.339	1	.562
Age Started smoking 3x/wk	16.1 ± 4.4	16.7 ± 4.8	15.6 ± 4.0	1.402	1, 85	.240

# of cigarettes/day	20.0 ± 9.5	21.2 ± 10.6	19.0 ± 8.3	1.219	1,85	.273
# of smokers in house	1.6 ± 8.2	.41 ± .74	2.7 ± 11.2	1.700	1, 85	.196
# prior quit attempts	5.2 ± 7.2	6.0 ± 9.1	4.4 ± 4.8	1.037	1, 85	.311
Longest abstinence, life (months)	11.4 ± 26.8	14.3 ± 34.3	8.9 ± 17.6	.880	1, 85	.351
Longest abstinence, past year (months)	.11 ± .42	.07 ± .35	.15 ± .47	.782	1, 85	.379

Effects of Mindfulness Training on Smoking

Brewer et al reported that compared to those randomized to the FFS intervention, individuals who received MT showed a greater rate of reduction in cigarette use during treatment and maintained these gains during follow-up ($F = 11.11$, $p = .001$). They also exhibited a trend toward greater point prevalence abstinence rate at the end of treatment (36% vs. 15%, $p = .063$), which was significant at the 17-week follow-up (31% vs. 6%, $p = .012$) [22].

Correlations between Craving and Cigarette Use

The relationship between craving and smoking behavior at baseline, the end of treatment, and during follow-up among those subjects who received mindfulness training was examined utilizing Pearson Product Moment correlations. Scatter plots were inspected for wayward points, of which there were none. At the start of the 4-week treatment period, a strong positive correlation ($r = 0.582$, $p < 0.001$) was revealed

between average daily cigarette use and self-reported craving for cigarettes, as measured by the Questionnaire on Smoking Urges (See Table 2). In other words, those who smoked more cigarettes tended to also report higher levels of craving. 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 ($z = 2.05$, $p = 0.04$).

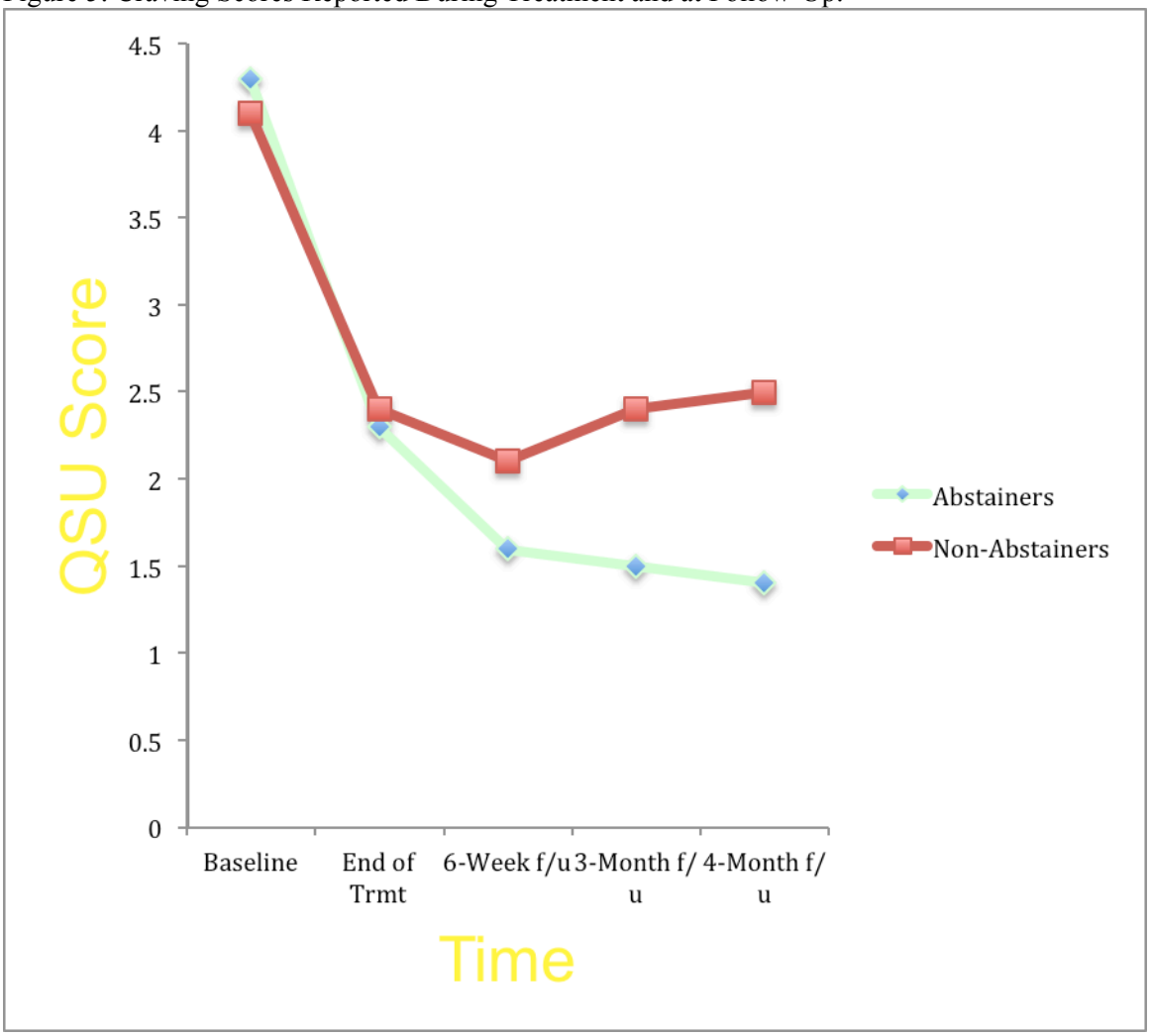
A positive correlation reappeared again at follow-up two weeks after the end of treatment ($r = 0.47$, $p < 0.02$), and grew stronger both three ($r = 0.79$, $p < 0.001$) and four months after treatment initiation ($r = 0.77$, $p < 0.001$) as shown in Table 2. This was likely due to an increased spread in the data (e.g. people who were abstinent at the follow up time points reported lower levels of cravings and fewer cigarettes smoked, while those that continued to smoke, reported higher levels of craving and smoking) (Figure 2). Interestingly, craving scores at the end of treatment were the same for individuals who quit smoking and those who did not (Figure 5).

Table 2: Correlations between craving and cigarette use, in relation to home practice with Mindfulness Training

Variables	Baseline (Week 0)	End of Treatment (Week 4)	6-Week Follow-Up	3-Month Follow-Up	4-Month Follow-Up
Craving 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**

Craving was measured by the Questionnaire on Smoking Urges (QSU).
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) / SOBER (Stop, Observe, Breathe, Expand, Respond).

Figure 5: Craving Scores Reported During Treatment and at Follow-Up.



"Abstainers" refers to those subjects who were abstinent from smoking at the 4-month follow-up. "Non-Abstainers" refers to those subjects who were not abstinent at the 4-month follow-up. Craving was measured by the Questionnaire on Smoking Urges (QSU).

Pearson Product Moment correlations were also utilized to compare craving scores and daily cigarette use in the FFS control group. For those subjects treated in the FFS group, a significant positive correlation can be seen between craving and daily

cigarette use at baseline (r = 0.361, p = .031), but not at any other time point. It should be noted that an outlying data point was removed from the baseline data after inspection of the scatter plot. Prior to the removal of the outlier, the correlation was weakly positive and non-significant (r = 0.248, p = .139). The removal of the outlier was decided based upon the fact that it was 2.081 SD deviations away from the mean, as determined by standardized residuals following a linear regression analysis.

Craving and Mindfulness Home Practice as Predictors of Cigarette Use

As we had previously found that increased home practice was correlated with decreased cigarette use for both formal (r = -0.44, p < 0.02) and informal practice (r = -0.48, p < 0.01) [22], we next examined the relationship between craving and average daily cigarette use using linear regression. (Of note, although both groups (MT and FFS) reported home practices as part of their assigned treatment, only individuals receiving mindfulness training demonstrated significant correlations between home practice and smoking outcomes.)

Multiple regression analyses were performed to explore the relative contribution of craving and home practices in predicting average daily cigarette use. As seen in Table 3, at baseline prior to treatment initiation a regression model with craving as an independent variable was shown to predict 33.9% of the variance in the average number of cigarettes smoked daily (B= 3.45 ± 0.88, R^2=0.339, p < 0.001, df = 1, 31, f^2 = 0.51).

Following the 4-week treatment period, craving only explained 1.6% of the variance in smoking (B= 0.41 ± 0.59, R^2=0.016, p = 0.491, df = 1, 31, f^2 = 0.016).

When home practice was added to craving as a second independent variable in the regression equation, the model fit improved significantly. As seen in Table 3, for example, a model that included both craving and number of days of informal practice per week predicted 31.5% of the variance in average daily number of cigarettes smoked (β = -1.35 ± 0.29 ,R^2= 0.437, p < 0.0001, df = 2, 31, f^2 = 0.78). Thus, for every day of the week that individuals practiced, they smoked 1.35 fewer cigarettes. We observed the same relationship between home practice and craving when number of minutes of formal practice, days per week of formal practice, and number of times of informal practice were examined (Table 3). Here, individuals smoked .009 fewer cigarettes for each minute of formal practice, 1.33 fewer cigarettes for each additional day per week of formal practice, and .03 fewer cigarettes for each time they performed an informal practice. Effect sizes for these models ranged from .3 (medium to large) to .78 (large) (Table 3).

Table 3: Multivariable Regression Analyses, Average Daily Cigarette Use as Dependent Variable

Time Point	*Predictor Variable*	*r*	r^2	*a*	*b*	*SE a, b*	*β*	*p*	df	*f2*
Baseline (Week #0)	**Model**	**0.582**	**0.339**					**0.000**	**1, 31**	**0.51**
				5.18		**±3.71**	**na**	**0.173**		
	Craving				**3.45**	**±0.88**	**.58**	**0.000**		
Treatment End (Week #4)	**Model**	**0.126**	**0.016**					**0.491**	**1, 31**	**.016**
				3.18		**±1.56**	**na**	**0.051**		
	Craving				**0.41**	**±0.59**	**.13**	**0.491**		
	Model	**0.561**	**0.315**					**0.004**	**2, 31**	**0.46**
				10.30		**±2.41**	**na**	**0.000**		
	Craving + Formal (d/wk)				**0.47**	**±0.50**	**.14**	**0.358**		
					-1.33	**±0.38**	**-.55**	**0.001**		
	Model	**0.482**	**0.232**					**0.022**	**2, 31**	**0.30**
				6.39		**±1.80**	**na**	**0.001**		
	Craving + Formal (mins)				**0.33**	**±0.53**	**.10**	**0.533**		
					-0.009	**±0.003**	**-.47**	**0.008**		
	Model	**0.661**	**0.437**					**0.000**	**2, 31**	**0.78**
				10.62		**±2.47**	**na**	**0.001**		
	Craving + Informal (d/wk)				**0.46**	**±0.45**	**.14**	**0.321**		
					-1.35	**±0.29**	**-.65**	**0.000**		
	Model	**0.554**	**0.307**					**0.004**	**2, 31**	**0.44**
				6.00		**±1.56**	**na**	**0.000**		
	Craving + Informal (times)				**0.56**	**±0.50**	**.17**	**0.275**		
					-0.03	**±0.008**	**-.54**	**0.002**		

Craving was measured by the Questionnaire on Smoking Urges (QSU).
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) / SOBER (Stop, Observe, Breathe, Expand, Respond).

Moderation of the Relationship Between Craving and Smoking by Mindfulness Home Practice

Given the strong association between mindfulness practice and smoking, as well as the lack of an association between craving and smoking after four weeks of treatment, we were next interested in whether mindfulness home practice changed the association between craving and smoking over the course of treatment. To examine this question 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 cigarettes per day at four weeks following treatment. Results from the moderated regression indicated that days of informal practice significantly moderated the association between craving and smoking at four weeks following treatment (B= 0.52 ± 0.22, p = 0.03, f^2 = 0.18). A bivariate scatter plot for the association between craving and smoking at 4-weeks following treatment, at levels of informal practice, split into groups of individuals who practiced informally at least 6 out of 7 days (n = 21) as compared to those who practiced on fewer than 6 days (n = 11) suggesting that the association between craving and smoking is actually stronger in the group that practiced more (Figure 6). Yet, the individual data points indicated that 5 of the individuals who practiced daily and never smoked also reported higher levels of craving. Further inspection of this effect indicated that individuals who practiced informally at least 6 out of 7 days were smoking significantly fewer cigarettes per day (t

(30) = 3.10, p = 0.004, d = 1.05) than those who engaged in fewer than 6 days of practice, yet they were not reporting lower levels of craving (t (30) = -0.76, p = 0.45, d = .30). Thus individuals who engaged in more days of informal practice were experiencing similar levels of craving and were smoking significantly less than those who engaged in fewer days of informal practice (Figure 7).

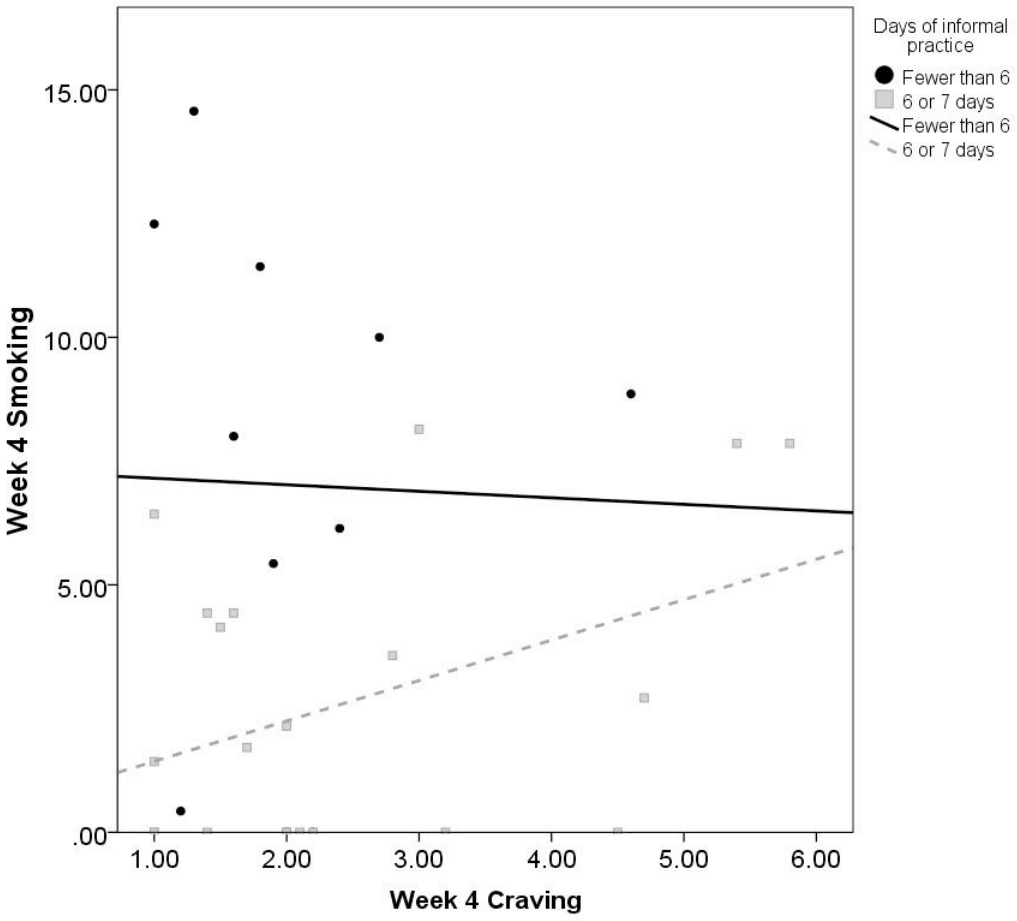


Figure 6: Bivariate scatter plot for the association between craving and smoking at 4-weeks following treatment, at levels of informal practice, split into groups of individuals who practiced informally at least 6 out of 7 days (n = 21) as compared to those who practiced on fewer than 6 days (n = 11)

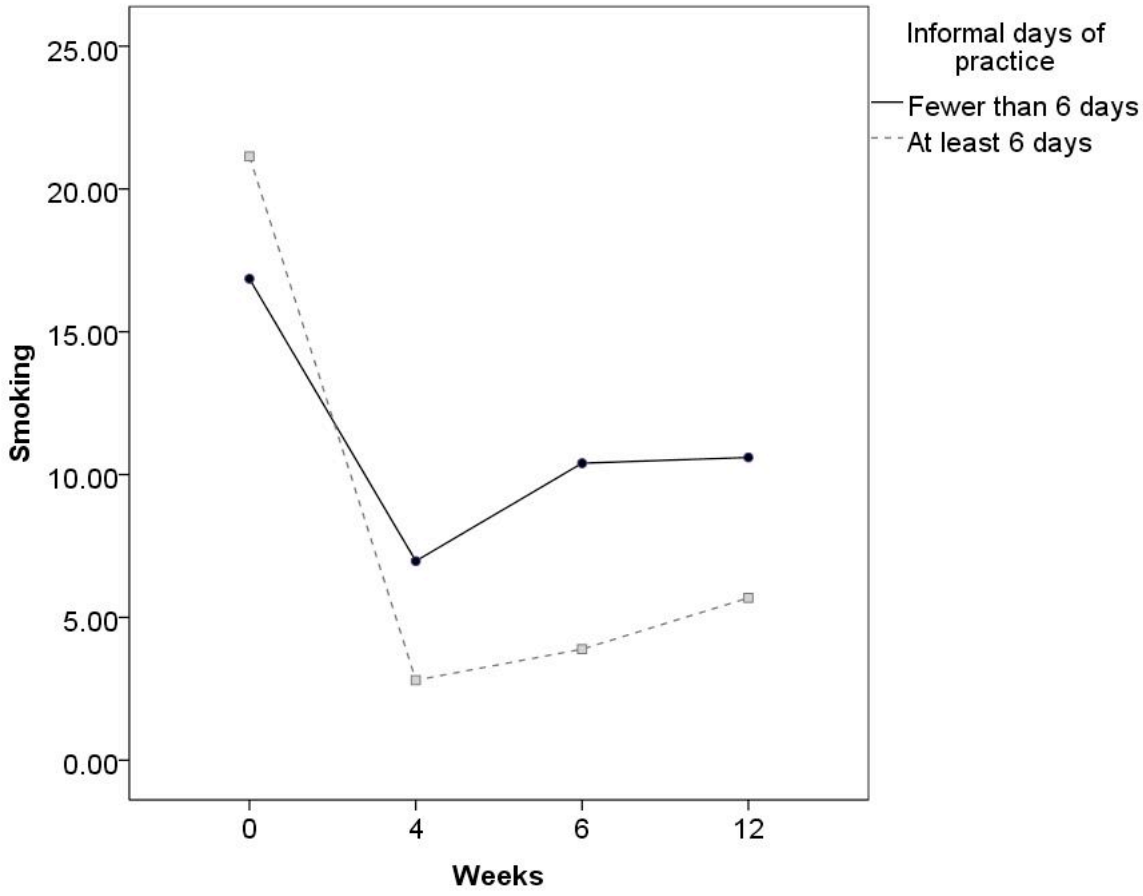


Figure 7: Moderating effect of the number of days per week of informal practice on the association between craving and smoking.

Discussion:

The primary aim of this study was to identify potential psychological mechanisms underlying the clinical effects of MT in reducing smoking. Given the theoretical underpinnings of MT, we hypothesized that the relationship between craving and smoking behavior would diminish after MT. The results of this analysis appear to support that hypothesis. Following four weeks of MT, the significant and strong positive correlation between craving and smoking behavior (r = 0.582, $p < .001$), seen among participants initially at baseline, is reduced in strength to the point of statistical non-significance (r = 0.126, $p < 0.126$). To the best of our knowledge, this is the first analysis to show that MT may decouple the positive correlation commonly seen between craving and smoking.

Multiple regression analyses further supported the hypothesis that after MT the relationship between craving and smoking behavior is diminished. At baseline, regression models reveal craving to significantly predict 33.9% of the variance in how many cigarettes are smoked per day (B= 3.45 ± 0.88, R^2=0.339, $p < 0.001$, df = 1, 31, f^2 = 0.51). Following the 4-week MT treatment period, craving only explained 1.6% of the variance in smoking (B= 0.41 ± 0.59, R^2=0.016, $p = 0.491$, df = 1, 31, f^2 = 0.016). Upon addition of home practice as a second independent variable, the regression models once again become significantly predictive of the number of cigarettes smoked per day. These models all showed large effect sizes (Cohen's f^2). Furthermore, regression analyses revealed that the amount of informal home practice as measured in days/week moderated the relationship between craving and smoking such that individuals were smoking less regardless of their level of craving.

These results suggest that the positive relationship between high levels of craving and frequency of smoking that has been consistently observed, i.e. the ability of craving level to predict smoking behavior can be specifically modified by targeted treatment, leading to a vastly different outcome [15 39 92 93 38 35]. As previously stated, MT may help participants to more effectively 'ride out' their cravings. Cravings could still arise, but the practice of sitting with urges, pausing and not immediately reacting to them, may disrupt the associative learning process and the automaticity of the action habitually taken. As hypothesized earlier, if this is indeed true then MT should affect the traditional observation that smoking and craving are positively correlated. Or, in other words, the success that a recipient of Mindfulness Training might have in cutting down or quitting smoking cigarettes would not necessarily due to, nor a consequence of, diminished craving, but instead due to a different relationship to craving. Taken together, these results suggest that mindfulness training may indeed help individuals develop a tolerance to craving itself, thus over time acting to dismantle the addictive loop. 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 healthier behavior, and leads to benefits for the individual and society.

Through specifically targeting craving, our data suggest that MT may confer several advantages over standard cognitive therapy for addictions (e.g. FFS). 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 2), it teaches individuals to simply observe and 'be with' cravings, no matter what triggers them (cue or affect). In such, it may help people

to learn one technique well, rather than dividing cognitive resources to learn several techniques [22]. This may be more supportive of successful quit attempts, especially in situations in which individuals are vulnerable to relapse, such as during strong affective states or when cognitively depleted [54], as mindfulness meditation has recently been shown to counteract self-control depletion in a laboratory setting [94]. Comparing these types of 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. A number of limitations of this study are worth mentioning. 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.

In conclusion, results from this study suggest that one possible psychological mechanism of how MT exerts its effect on smoking behavior is through decoupling the relationship between craving and smoking. Larger studies that not only replicate these findings but test other possible mechanisms of action as well are warranted.

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