Published in final edited form as:

Addiction. 2010 February ; 105(2): 364–372. doi:10.1111/j.1360-0443.2009.02760.x.

The Impact of Cigarette Deprivation and Cigarette Availability on Cue-Reactivity in Smokers

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Abstract

Aims—This experiment was conducted to determine the impact of cigarette deprivation and cigarette availability on reactivity measures to cigarette cues.

Participants—Smokers were recruited who were 18 years of age or older, not attempting to quit or cut down on their smoking, smoked at least 20 cigarettes daily, had been smoking regularly for past year, and had an expired carbon monoxide level of at least 10 ppm.

Design—Smokers were randomly assigned to abstain from smoking for 24 hours (N = 51) or continue smoking their regular amount (N = 50). Twenty-four hours later, they were exposed to trials of either a lit cigarette or a glass of water with a 0, 50 or 100% probability of being able to sample the cue on each trial. Craving, mood, heart rate, skin conductance, puff topography, and latency to access door to sample the cue were measured.

Findings—Both exposure to cigarette cues and increasing availability of those cues produced higher levels of craving to smoke. Deprivation produced a generalized increase in craving. There was no consistent evidence, however, that, even under conditions of high cigarette availability, deprived smokers were selectively sensitized to presentations of cigarette cues.

Conclusions—The data suggest that, even under conditions of immediate cigarette availability, deprivation and cue presentations have independent, additive effects on self-reported craving levels in smokers.

Keywords

cue-reactivity; craving; cigarette deprivation; cigarette availability

Introduction

Craving is a core feature of tobacco addiction [1,2]. Although there is continuing controversy about the nature and functional significance of craving, laboratory-based studies have isolated several factors that reliably modulate craving processes. In the case of cigarette smokers, smoking deprivation [e.g., 3,4], smoking related cues [5], stressors [6,7], induction of negative affect [e.g., 8,9], and alcohol intoxication [e.g., 10-12] readily increase craving to smoke. Less clear is the extent to which these conditions might interact to control craving processes.

Certain combinations of evocative stimuli could operate synergistically to produce especially intense levels of craving. In particular, nicotine deprivation might prime smokers' reactions to smoking related cues so that they would be hyper-reactive to those cues when abstinent from cigarettes. Indeed, such an effect might account for smokers' beliefs they will confront intense craving when they are deprived of cigarettes [13]. The proposal that abstinence should amplify cue-specific craving has considerable theoretical support. In their incentive motivational theory of drug addiction, Stewart and her colleagues [14] hypothesized that drug deprivation should increase the salience of drug cues and decrease the threshold for craving activation. Similarly, Baker and colleagues [15] invoked incentive motivational processes in predicting that drug deprivation should sensitize the craving responses of drug users to drug-related cues. These propositions are consistent with general incentive motivational models that presume that the salience of motivationally relevant cues is selectively modified by the deprivation state of the organism [e.g., 16-18].

Though plausible, the assumption that cigarette abstinence amplifies smokers' cue-specific craving has little empirical support. Maude-Griffin and Tiffany [9] found that smokers abstinent for six or twenty-four hours reported generalized elevations in craving relative to non-abstaining smokers. However, they obtained no evidence of any selective increase in deprived smokers' craving, mood, or physiological reactions to smoking-related cues. A similar pattern has been reported by numerous other researchers [19-26]. Abstinence-induced craving appears to be controlled by nicotine deprivation, as this effect is reversed by nicotine delivered via a nicotine patch [27,28]; however, nicotine patches have no impact on cue-specific craving [28-30].

Although there is little indication of synergistic interactions between nicotine abstinence and cue-specific craving, that conclusion has to be qualified by the fact that smokers in these studies had no access to cigarettes when presented with smoking related cues. Many researchers have posited that expectations of drug availability may regulate addicts' craving responses to drug stimuli [15,31-36]. The opportunity to smoke a cigarette immediately after the presentation of a smoking cue can markedly increase the level of craving to the cue presentation [e.g., 37,38]. The unavailability of cigarettes might moderate the impact of abstinence on craving reactivity to smoking cues. Given that immediate cigarette availability can amplify craving to smoking related cues, cigarette unavailability may suppress any heightened cue reactivity that deprived smokers might normally display if given the opportunity to smoke.

This hypothesis was partially evaluated by McBride and colleagues [39] who examined the joint impact cigarette abstinence and smoking availability on cue-induced cigarette craving. In that study, availability was manipulated by telling participants that they could or could not smoke after the cue session was completed. Both abstinence and expectancy of post-session smoking significantly elevated craving to smoke, but these factors did not interact. The conclusions from this study were limited by the absence of direct evidence that the availability manipulation enhanced cue-specific craving. This is not surprising, as cigarette availability is likely to have the greatest impact when smokers can smoke immediately in the presence of the cue [37]. Indeed, research by Sayette et al. [38] suggests that the cue-specific availability effect dissipates if smokers have to wait more than 15 seconds to smoke after presentation of smoking stimuli.

The present study evaluated the impact of cigarette deprivation and immediate cigarette availability on reactivity measures using the Cue-Availability Paradigm [CAP, 37]. The CAP examines the effects of cigarette availability by manipulating the smoker's immediate access to cigarettes throughout the cue-reactivity session. Research with the CAP has shown that increased cigarette availability increased cue reactivity as indexed by stronger craving

report, enhanced positive mood, higher skin conductance, and shorter latency to access the cigarette in comparison to neutral trials [37]. If cigarette availability moderates the impact of abstinence on smokers' craving reactions to smoking cues, then nicotine-deprived smokers who are exposed to a cigarette they believe they can smoke immediately should display disproportionately stronger craving reactions to that cue relative to non-deprived smokers under the same availability conditions. In contrast, the manipulation of cigarette availability may have no impact on cue-specific craving during cigarette deprivation, suggesting that, even under conditions of immediate availability, nicotine-deprived smokers are not hyper-reactive to smoking related cues.

Method

Participants

A total of 119 (M = 60, F = 59) smokers were recruited from the local community using flyers and newspaper advertisements. Eligible participants were 18 years of age or older, not attempting to quit or cut down on their smoking, smoked at least 20 cigarettes daily, had been smoking regularly for past year, and had an expired carbon monoxide (CO) level of at least 10 ppm.

Procedures

Session 1—Participants signed a consent document and CO levels were assessed with a Vitolograph CO monitor. Participants completed the Mood Form [40] and the Questionnaire on Smoking Urges [QSU; 41]. Participants then smoked one cigarette through the mouthpiece of the CReSS (Clinical Research Support System; Plowshare Technology) while completing a Smoking History Form. Participants were then assigned randomly to either the Deprived or Non-Deprived group. Those in the Deprived group were instructed to remain abstinent from cigarettes or any form of nicotine for the next 24 hours. They were told that smoking would be detectable by the CO analysis at the next session. Participants in the Non-Deprived group were instructed to smoke at their usual rate between sessions. At the end of Session 1, participants selected a slip of paper from a box, assigning them to either the deprived or smoking condition. All participants received \$60 for being in the study. Those in the Deprived group received a \$30.00 bonus if they remained completely abstinent between sessions.

Session 2—At the beginning of this 90-minute session, CO levels were determined and participants completed the QSU, Mood Form, and Withdrawal Symptoms Checklist [WSC; 41]. Participants in the Non-Deprived group then smoked a cigarette. Participants in the Deprived group were asked to report any form of tobacco use over the inter-session interval. The CO criterion for deprivation was a minimum 60% reduction in CO levels from Session 1. If a participant did not meet the CO criterion at Session 2, the slip of paper for group assignment was returned to the box until we were able to reach our target enrollment.

Heart rate and skin conductance were collected as described in Carter and Tiffany [37]. Participants were seated in front of a computer monitor and keyboard and wore headphones. A stimulus box, with a clear-glass sliding door on the front, was set into the wall over the table. A flip-down board on a hinge with a holder for the CReSS mouthpiece was inside the box. The hinged apparatus allowed for either a lit cigarette to be placed in the mouthpiece or for a plastic cup of water to be placed on a flat surface of the box. A new cigarette was used for each cigarette trial and the water cup was refilled on each water trial.

The CAP session consisted of 48 trials (24 cigarette, 24 water) with a 0, 50, or 100% probability of being able to open the door on each trial. Cue and probability levels were

pseudo-randomized across four blocks of 12 trials each (see [37], for randomization procedures). At the beginning of the session, participants closed their eyes and waited for a tone to be presented over the headphones. At the tone, participants opened their eyes and were given the following information on the monitor: "You have a (0%, 50%, 100%) chance of opening the door. Look in the box and think carefully about what you see." A light display below the glass door also indicated the probability in effect for that trial. After 8 seconds, a tone was delivered, and participants rated cigarette craving and mood items presented on the monitor by entering a number on a 1 to 7 scale via the keyboard. Cigarette craving was measured by a 4-item subscale of the QSU [4; see 37, for item wording]. All items were presented in a randomized order with the craving questions always presented first.

After the final item was rated, participants waited for eight seconds. This period was terminated by a tone and instructions to attempt to open the door and sample the cue (either a sip of water or one puff of the cigarette as explained by a research assistant prior to the CAP session). The CReSS recorded puff topography on the cigarette trials. Participants were told that they should attempt to open the door on 0% probability trials to equate the level of physical movement across every trial. Latency (in msec) was recorded on every trial through a micro-switch located in the door of the stimulus box. Participants were then instructed to close the door, close their eyes, and wait for the tone signaling the next trial. On trials that the door was locked, participants were instructed to close their eyes after attempting to open the door. The interval between trials averaged 30 seconds. Across all participants, the average CAP session duration was 61 minutes (range 53 – 78 min) with an average inter-puff interval of approximately 5 minutes. All participants sampled the cigarette on all available trials.

Data Reduction and Analyses

All CAP data were analyzed with a $2 \times 2 \times 3 \times 4$ (Group $\times$ Cue Type $\times$ Probability $\times$ Block) mixed-design analysis of variance. The Greenhouse-Geisser technique was employed to control for heterogeneity of covariance across repeated measures. Previous research with the CAP indicated that the most pronounced physiological effects occurred during the four seconds just prior to attempting to open the door. Therefore, analyses of the physiological measures focused on this period. Correlational analyses were conducted to determine the extent to which relationships between craving and mood and craving and latency measures reported by Carter and Tiffany [37] were replicated in the present study.

Results

Participants

The average participant was 30 years old (range 18 – 61), smoked 25 cigarettes daily ($SD = 9.12$), and smoked his/her first cigarette at 13.7 years of age (range 5 – 23). There were 50 participants in the Non-Deprived group ($M = 25$, $F = 25$) and 51 participants ($M = 25$, $F = 26$) assigned to the Deprived group who met the CO criterion. The average CO level was 31 ppm ($SD = 16.34$); Deprived=28 ppm, Non-Deprived=35 ppm; *ns*) at Session 1, and 4.2 ($SD = 3.63$) and 33.7 ppm ($SD = 16.76$) for the Deprived and Non-Deprived groups, respectively, at Session 2. On average, smokers in the Deprived condition had an 84% decrease in their CO levels from Session 1 to Session 2. Participants in the Non-Deprived group reported smoking their last cigarette an average of 23.4 minutes (range of 5 - 600 minutes; median = 10 minutes) prior to the start of Session 2. An additional 18 individuals (10 males, 8 females) assigned to the Deprived group were excluded from analyses as they did not meet the abstinence criteria. These individuals did not differ significantly from those who met the abstinence criteria on any Session 1 measures.

Questionnaires

There were no significant differences between groups at Session 1 on the QSU or Mood Form. At the beginning of Session 2, relative to the Non-Deprived group, smokers in the Deprived group reported significantly stronger craving to smoke on the General Factor scale and both subscales of the QSU, $F_s(1,99) \geq 15.32$, $p_s < .001$, significantly stronger negative mood on the Mood Form $F(1,99) = 6.40$, $p < 0.05$, and significantly higher scores on the Craving, Psychological Discomfort, and Physical Symptoms scales of the WSC, $F_s(1,99) \geq 6.56$, $p_s < .05$.

CAP Trials

Craving—During CAP trials (Figure 1), participants in the Deprived group reported significantly higher craving for cigarettes than those in the Non-Deprived group, $F(1,99) = 7.41$, $p < .01$. Participants also reported significantly stronger craving on cigarette trials compared to water trials, $F(1,99) = 107.44$, $p < .0001$. Craving became significantly stronger as the probability increased that the participant could open the door and sample the cue, $F(2, 198) = 39.74$, $p < .0001$; however, an evaluation of a significant Cue $\times$ Probability interaction, $F(2, 198) = 10.05$, $p < .0001$, revealed that the increase in craving by probability level was only significant on cigarette trials. There were no significant interactions between the abstinence manipulation and either cue or probability factors and no significant effects involving the block factor.

Mood—The deprivation manipulation (Deprived vs. Non-Deprived) produced no significant main effects or interactions on mood ratings collected during CAP. The manipulation of cues and probability produced complimentary effects on mood ratings; negative mood decreased and positive mood increased with greater probability that the door would be unlocked on cigarette trials (Table 1). There were significant interactions between cue type and probability for both positive and negative mood ratings, $F_s(2,198) \geq 23.13$, $p_s < .0001$, where cigarette trials produced significantly higher negative mood ratings and lower positive mood ratings than water trials on the 0% probability level. This pattern was reversed on the 100% probability level with negative mood ratings significantly lower and positive mood ratings significantly higher on cigarette trials compared to water trials.

Puff topography—Due to equipment malfunction, complete CReSS data were not available from 15 participants (7 in the Deprived group and 8 in the Non-Deprived group). Among those participants with complete CReSS data, there were no significant main effects or interactions on either Puff Duration or Maximum Flow. Puff Volume was significantly higher for the Non-Deprived Group ($M = 64.64$ ml, $SD = 17.83$) than for the Deprived group ($M = 58.90$ ml, $SD = 20.66$), $F(1, 84) = 4.12$, $p < 0.05$. Participants also had significantly greater Puff Volume on the 100% trials ($M = 62.70$ ml, $SD = 19.31$) relative to 50% trials ($M = 60.84$ ml, $SD = 19.18$), $F(1, 84) = 4.34$, $p < 0.05$.

Latency—The Deprived group had significantly shorter latencies to access the door than the Non-Deprived group, $F(1,98) = 4.45$, $p < .05$. There was also a significant probability effect, $F(2,196) = 26.12$, $p < .0001$, a block effect, $F(3, 294) = 9.17$, $p < .0001$, a Cue $\times$ Probability interaction, $F(2,196) = 3.24$, $p < .05$, and a Group $\times$ Probability interaction, $F(2,196) = 4.15$, $p < .05$. Latency on both cigarette and water trials were shorter with increasing probability of being able to open the door for both groups (see Table 2). In general, door opening latencies decreased across trial blocks. Plotting the Cue $\times$ Probability interaction revealed a crossover effect such that, unlike at the 50% and 100% probability levels where cigarette trials had shorter latencies than water trials, the opposite was true at the 0% probability trials. Analysis of the Group $\times$ Probability interaction revealed a

significant difference between the Deprived and the Non-Deprived groups at 50% and 100% probability levels with shorter latencies for both cues types for the Deprived group.

Physiological Responses

Skin Conductance—There were no significant baseline differences between the Deprived and Non-Deprived groups. During the four seconds just prior to attempting to open the door (see Figure 2), the Deprived group had significantly higher levels of skin conductance than the Non-Deprived group, $F(1, 99) = 4.82, p < .05$. Across both groups, cigarette trials were associated with higher levels of skin conductance than water trials, $F(1, 99) = 48.97, p < .0001$. There was also a main effect for Probability, $F(2, 198) = 10.19, p < .0001$, a significant Cue $\times$ Group interaction, $F(1, 99) = 6.65, p < .05$, Cue $\times$ Probability interaction, $F(2, 198) = 4.73, p < .05$, and a Cue $\times$ Probability $\times$ Group interaction, $F(2, 198) = 6.57, p < .01$. Analysis of the Cue $\times$ Probability interaction revealed that the difference in skin conductance between cigarette and water trials at the 100% probability level was significantly larger than the difference at both the 0% and 50% probability levels. Analysis of the Cue $\times$ Group and the Cue $\times$ Probability $\times$ Group interactions revealed that this difference between cue trials at the 100% probability level compared to the 0% and 50% probability levels was significant for the Deprived group only.

Heart Rate—There were no significant effects in the analyses of the heart rate data.

Correlational Analysis

Carter and Tiffany [37] found that the strongest associates of craving on trials where the cue reactivity effects were the most pronounced (i.e., 100% cigarette trials) were the negative mood ratings collected from trials where cigarettes were unavailable (i.e., 0% cigarette trials). In contrast, the mood ratings (either negative or positive mood) on 100% cigarette trials were not significantly correlated with craving ratings on those same trials. The mood-craving correlations from the present study replicated this pattern. Negative mood on cigarette trials when there was a 0% or 50% probability of being able to open the door was significantly correlated with craving on 100% cigarette trials for both groups (see Table 3). For the Deprived group only, positive mood on cigarette trials when there was a 0% probability of being able to open the door was significantly correlated (negatively) with craving on cigarette trials.

Every correlation between latency to access the door on cigarette trials and craving on both the cigarette and water trials was significant for the Deprived Group. All of these correlations were negative (r s ranged from $-.282$ to $-.473$; median = $-.382, p \leq .05$) with the strongest correlation between craving and latency on the cigarette trials with 100% probability to sample the cue. For the Non-Deprived group, the only significant correlation was between craving on 50% probability cigarette trials and latency on 100% probability cigarette trials ($r = -.307, p < .05$). There were no other significant correlations across self-reports, physiological responding, or latency.

Discussion

As has been found in previous studies [2,37], 24 hours of cigarette deprivation produced generalized increases in craving, and immediate cigarette availability boosted craving reactivity to smoking related cues. Deprivation-enhanced craving was evident in multidimensional craving and nicotine withdrawal questionnaires administered just prior to the cue manipulation as well as on the craving measure given repeatedly during the cue-availability procedure. Despite the robust main effects for cigarette deprivation and

availability, there was no consistent evidence that, even under conditions of immediate cigarette availability, deprivation selectively enhanced cue-induced craving.

In contrast to the common expectation that abstinence should sensitize cue-reactive craving, Powell and colleagues [26] found that overnight cigarette abstinence reduced cue-reactive craving relative to a non-abstinent condition. In that study, cue-reactivity was indexed as a difference from baseline responding, a procedure that may provide a less sensitive assessment than measuring reactivity as response difference between drug cues and neutral cues [42]. Indeed, a subsequent study from that same group [43], in which cue reactivity was indexed as craving differences between smoking and neutral cues, found no evidence that abstinence moderated the magnitude of cue-reactive craving.

The finding that negative mood was elevated on cigarette trials relative to neutral cues parallels mood effects observed in conventional cue-reactivity studies in which smokers have no immediate access to cigarettes during cue exposures (see [44] for review). The reversal of this pattern when cigarettes were immediately accessible replicates previous CAP findings [37]. Thus, the mood ratings were sensitive to both the cue and availability manipulation but were not affected by cigarette deprivation. There also was no evidence in the mood ratings of any interactions between deprivation and cue reactivity or between deprivation and cigarette availability. That is, as with craving, there was no indication in mood report of any abstinence-induced sensitization to smoking cues.

The fact that both craving and positive mood increased with cigarette availability may suggest that smokers were expressing pleasure in anticipation of smoking [15,45]; however, there was no evidence that positive mood was indexing the emotional valence of craving as there were no significant positive correlations between craving report and positive mood. An alternative hypothesis is that smokers were expressing relief that they could smoke on 100% probability cigarette trials and frustration when they knew they could not smoke or were uncertain of cigarette availability [37]. The finding that positive correlations between negative mood and craving were significant at the 0% and 50% probability levels, but not at the 100% probability level, lends support to this interpretation. This pattern of mood results complements previous findings from other studies that negative mood, not positive mood, is most clearly linked with craving processes (see [44] for review).

Although the self-report data did not support the predictions derived from several incentive motivational models of the impact of deprivation on reactivity to motivationally relevant cues, there was evidence in skin conductance responses of an interaction between abstinence and smoking cues. As has been observed in previous research [e.g., 19], skin conductance responses were larger in the presence of cigarette cues relative to water cues. In addition, deprived smokers, but not non-deprived smokers, showed particularly strong skin conductance responses to cigarette cues on 100% availability trials. The magnitude of the difference in skin conductance responses between the Deprived and Non-Deprived groups on these trials was fairly robust (means of .32 and .13 μ -siemens, respectively), with an estimated effect size of .72 (Cohen's *d*). To the best of our knowledge, the finding of increased skin conductance reactivity to smoking cues under conditions of cigarette deprivation has not been reported previously in the literature. This pattern, if replicated, suggests that skin conductance may offer unique information about motivational processes activated by smoking cues in a deprived condition. More generally, these divergent patterns across self-report and physiological measures illustrate that cue-reactivity responses are not uniform indices of a homogenous drug-motivational state. Indeed, the absence of significant correlations between skin conductance and self-reported craving suggest that these two measures of reactivity may be tracking somewhat independent processes.

We found that craving to smoke was significantly correlated with latency to access the door on both water and cigarette cue trials, but these relationships were restricted almost exclusively to smokers in the Deprived group. This finding parallels results reported by Sayette and colleagues [46], who found that measures of craving-related processes were more strongly inter-related when smokers were abstinent from cigarettes for seven hours. A pattern of enhanced cohesiveness between craving and drug-use measures under conditions of cigarette deprivation is consistent with the proposal of Baker et al. [15] that correlations between various manifestations of drug-motivational states should increase when drug-use motivation is strongest. In the current study, this pattern was not generalized across all craving correlates. That is, the relationships between mood measures and craving did not differ as a function of deprivation. Moreover, the correlations between craving and latency measures were not markedly affected by the cue-content of the exposure trials. These results indicate that, similar to the main effects of deprivation on craving, deprivation promoted greater cohesiveness among craving and certain other measures, but these correlations were not necessarily cue-specific.

When examining the impact of abstinence on craving reactivity, it is useful to employ procedures that maximize the possibility of detecting cue effects across a wide span of response levels. The CAP allowed for the assessment of craving responses across a range of stimulus intensities (i.e., availability), aggregated numerous cue trials at each level of cue type and availability, assessed craving directly in the presence of the cue, indexed craving reactivity relative to a neutral cue condition, and measured craving as the average of multiple items. Collectively, these features produced a craving assessment that was reliable, highly sensitive to cue manipulations, and not prone to ceiling effects that might have limited the detection of synergistic interactions between cue effects and abstinence. These considerations, in combination with the relatively large sample size used in this research, suggest that the absence of any enhanced reactivity to smoking cues under conditions of abstinence was not due to an insensitivity of craving assessment or lack of experimental power.

There are some limitations of this study that should be noted. Participants knew they could resume smoking immediately after the session and were only deprived of smoking for 24 hours. Smokers actively pursuing quitting and/or abstinent for a longer duration may show enhanced sensitivity to cigarette related stimuli. Nevertheless, it was clear from the self-report measures that the deprived smokers were experiencing symptoms of withdrawal and stronger craving than those in the non-deprived condition. Another factor that may have affected the results, particularly the lack of significant differences in heart rate between groups, is that smokers in the Deprived group were exposed to 12 puffs of a cigarette during the CAP. Although allowing people to smoke also could have affected craving levels, the amount smoked was equal to approximately one cigarette, a significantly lower amount than their typical smoking behavior. Furthermore, there were no significant block effects, suggesting that craving did not significantly change over the course of the session.

Our data are consistent with the hypothesis that deprivation and smoking cue presentations have independent, additive effects on craving levels in smokers. Beyond the conceptual implications for models of craving and drug-use motivation, these results have important ramifications for the assessment and treatment of craving. Several studies of the effects of transdermal nicotine patches on cue-elicited craving in smokers have shown that the nicotine patch had no significant impact on craving generated by smoking-related cues [28-30]. Such results suggest that treatment may have to selectively target craving arising from cue-induced craving and deprivation-induced craving. More generally, the present data underscore the value of distinguishing between deprivation-induced and cue-induced craving for cigarettes [2].

Acknowledgments

This research was funded by an NIH grant R01 DA10264 awarded to S. Tiffany. We thank Virginia A. Edwards and Angela Begle for their help during the data collection phase of this study.

References

- Goedeker KC, Tiffany ST. On the nature of nicotine addiction: A taxometric analysis. *J Abnorm Psychol.* 2008; 117:896–909. [PubMed: 19025235]
- Tiffany ST, Warthen MW, Goedeker KC. The functional significance of craving in nicotine dependence. *Nebr Symp Motiv.* 2009; 55:171–197. [PubMed: 19013944]
- Schuh KJ, Stitzer ML. Desire to smoke during spaced smoking intervals. *Psychopharmacology.* 1995; 120:289–295. [PubMed: 8524976]
- Tiffany ST, Drobes DJ. The development and initial validation of a questionnaire on smoking urges. *Br J Addict.* 1991; 86:1467–1476. [PubMed: 1777741]
- Carter BL, Tiffany ST. Meta-analysis of cue-reactivity in addiction research. *Addiction.* 1999; 94:327–340. [PubMed: 10605857]
- Payne TJ, Schare ML, Levis DJ, Colletti G. Exposure to smoking-relevant cues: Effects on desire to smoke and topographical components of smoking behavior. *Addict Behav.* 1991; 16:467–479. [PubMed: 1801570]
- Perkins KA, Grobe JE. Increased desire to smoke during acute stress. *Br J Addict.* 1992; 87:1037–1040. [PubMed: 1643396]
- Conklin CA, Perkins KA. Subjective and reinforcing effects of smoking during negative mood induction. *J Abnorm Psychol.* 2005; 114:153–164. [PubMed: 15709822]
- Maude-Griffin PM, Tiffany ST. Production of smoking urges through imagery: The impact of affect and smoking abstinence. *Exp Clin Psychopharmacol.* 1996; 4:198–208.
- Burton SM, Tiffany ST. The effect of alcohol consumption on craving to smoke. *Addiction.* 1997; 92:15–26. [PubMed: 9060194]
- Epstein M, Sher TG, Young MA, King AC. Tobacco chippers show robust increases in smoking urge after alcohol consumption. *Psychopharmacology.* 2007; 190:321–329. [PubMed: 16804691]
- Sayette MA, Martin CS, Wertz JM, Perrott MA, Peters AR. The effects of alcohol on cigarette craving in heavy smokers and tobacco chippers. *Psychol Addict Behav.* 2005; 19:263–270. [PubMed: 16187804]
- Sayette MA, Loewenstein G, Kirchner TR, Travis T. Effects of smoking urge on temporal cognition. *Psychol Addict Behav.* 2005; 19:88–93. [PubMed: 15783282]
- Stewart J, deWit H, Eikelboom R. Role of unconditioned and conditioned drug effects in self-administration of opiates and stimulants. *Psychol Rev.* 1984; 91:251–268. [PubMed: 6571424]
- Baker, TB.; Morse, E.; Sherman, JE. The motivation to use drugs: A psychobiological analysis of urges. In: Rivers, PC., editor. *The Nebraska Symposium on Motivation: Alcohol and addictive behavior.* Lincoln, NE: University of Nebraska Press; 1987. p. 257–323.
- Bindra D. How adaptive behavior is produced: A perceptual-motivational alternative to response-reinforcement. *Behav Brain Sci.* 1978; 1:41–91.
- Nader K, Bechara A, van der Kooy D. Neurobiological constraints on behavioral models of motivation. *Annu Rev Psychol.* 1997; 48:85–114. [PubMed: 9046556]
- Berridge, KC.; Robinson, TE. Automatic Processes in Addiction: A Commentary. In: Wiers, RW.; Stacy, AW., editors. *Handbook of implicit cognition and addiction.* Thousand Oaks, CA, US: Sage Publications, Inc.; 2006. p. 477–481.
- Drobes DJ, Tiffany ST. Comparisons of smoking urges elicited through imagery and in vivo cue-exposure. *J Abnorm Psychol.* 1997; 106:15–25. [PubMed: 9103714]
- Dawkins L, Powell JH, West R, Powell J, Pickering A. A double-blind placebo controlled experimental study of nicotine: I-effects on incentive motivation. *Psychopharmacology.* 2006; 189:355–367. [PubMed: 17047930]

21. McClernon FJ, Hiott FB, Huettel SA, Rose JE. Abstinence-induced changes in self-report craving correlate with event-related fMRI responses to smoking cues. *Neuropsychopharmacology*. 2005; 30:1940–1947. [PubMed: 15920499]
22. McBride D, Barrett SP, Kelly JT, Aw A, Dagher A. Effects of expectancy and abstinence on the neural response to smoking cues in cigarette smokers: An fMRI study. *Neuropsychopharmacology*. 2006; 31:2728–2738. [PubMed: 16598192]
23. McClernon FJ, Kollins SH, Lutz AM, Fitzgerald DP, Murray DW, Redman C, Rose JE. Effects of smoking abstinence on adult smokers with and without attention deficit hyperactivity disorder: results of a preliminary study. *Psychopharmacology*. 2008; 197:95–105. [PubMed: 18038223]
24. McDonough BE, Warren CA. Effects of 12-h tobacco deprivation on event-related potentials elicited by visual smoking cues. *Psychopharmacology*. 2001; 154:282–291. [PubMed: 11351935]
25. Payne TJ, Smith PO, Sturges LV, Holleran SA. Reactivity to smoking cues: mediating roles of nicotine dependence and duration of deprivation. *Addict Behav*. 1996; 21:139–154. [PubMed: 8730517]
26. Powell J, Dawkins L, Davis RE. Smoking, reward responsiveness, and response inhibition: tests of an incentive motivational model. *Biol Psychiatry*. 2002; 51:151–163. [PubMed: 11822994]
27. Teneggi V, Tiffany ST, Squassante L, Milleri S, Ziviani L, Bye A. Smokers deprived of cigarettes for 72 hours: Effect of nicotine patches on craving and withdrawal. *Psychopharmacology*. 2002; 164:177–187. [PubMed: 12404080]
28. Tiffany ST, Cox LS, Elash CA. Effects of transdermal nicotine patches on abstinence-induced and cue-elicited craving in cigarette smokers. *J Consult Clin Psychol*. 2000; 68:233–240. [PubMed: 10780123]
29. Morissette SB, Palfai TP, Gulliver SB, Spiegel DA, Barlow DH. Effects of transdermal nicotine during imaginal exposure to anxiety and smoking cues in college smokers. *Psychol Addict Behav*. 2005; 19:192–198. [PubMed: 16011390]
30. Waters AJ, Shiffman S, Sayette MA, Paty JA, Gwaltney CJ, Balabanis MH. Cue-provoking craving and nicotine replacement therapy in smoking cessation. *J Consult Clin Psychol*. 2004; 72:1136–1143. [PubMed: 15612859]
31. Childress AR, McLellan AT, O'Brien CP. Conditioned responses in a methadone population: A comparison of laboratory, clinic and natural settings. *J Subst Abuse Treat*. 1986; 3:173–179. [PubMed: 3806730]
32. Ehrman RN, Robbins SJ, Childress AR, O'Brien CP. Conditioned responses to cocaine-related stimuli in cocaine abuse patients. *Psychopharmacology*. 1992; 107:523–529. [PubMed: 1603895]
33. Meyer, RE. Conditioning phenomena and the problem of relapse in opioid addicts and alcoholics. In: Ray, RB., editor. *Learning Factors in Substance Abuse*. Washington DC: US Department of Health and Human Services; 1988. p. 161-179.
34. Plasecki TM, Smith SS, Baker TB. The tyranny of habit and availability. *Addiction*. 1999; 94:341–343. [PubMed: 10605858]
35. Wertz JM, Sayette MA. A review of the effects of perceived drug use opportunity on self-reported urge. *Exp Clin Psychopharmacol*. 2001; 9:3–13. [PubMed: 11519632]
36. Turkkan JS, McCaul ME, Stitzer ML. Psychophysiological effects of alcohol-related stimuli: II. Enhancement with alcohol availability. *Alcohol Clin Exp Res*. 1989; 13:392–398. [PubMed: 2665554]
37. Carter BL, Tiffany ST. The cue-availability paradigm: the effects of cigarette availability on cue reactivity in smokers. *Exp Clin Psychopharmacol*. 2001; 9:183–190. [PubMed: 11518094]
38. Sayette MA, Wertz JM, Martin CS, Cohn JF, Perrott MA, Hobel J. Effects of smoking opportunity on cue-elicited urge: A facial coding analysis. *Exp Clin Psychopharmacol*. 2003; 11:218–227. [PubMed: 12940501]
39. McBride D, Barrett SP, Kelly JT, Aw A, Dagher A. Effects of expectancy and abstinence on the neural response to smoking cues in cigarette smokers: An fMRI study. *Neuropsychopharmacology*. 2006; 31:2728–2738. [PubMed: 16598192]
40. Diener E, Emmons RA. The independence of positive and negative affect. *J Pers Soc Psychol*. 1984; 47:1105–1117. [PubMed: 6520704]

41. Shiffman S, Jarvik ME. Smoking withdrawal symptoms in two weeks of abstinence. *Psychopharmacology*. 1976; 50:35–39. [PubMed: 827760]
42. Warthen MW, Tiffany ST. Evaluation of cue reactivity in the natural environment of smokers using ecological momentary assessment. *Exp Clin Psychopharmacol*. In press.
43. Dawkins L, Powell JH, West R, Powell J, Pickering A. A double-blind placebo controlled experimental study of nicotine: I--effects on incentive motivation. *Psychopharmacology*. 2006; 189:355–367. [PubMed: 17047930]
44. Tiffany, ST. Drug craving and affect. In: Kassel, J., editor. *Substance Abuse and Emotion*. Washington, D.C: American Psychological Association; in press
45. Zinser MC, Baker TB, Sherman JE, Cannon DS. Relation between self-reported affect and drug urges and cravings in continuing and withdrawing smokers. *J Abnorm Psychol*. 1992; 101:617–629. [PubMed: 1430600]
46. Sayette MA, Martin CS, Hull JG, Wertz JM, Perrot MA. Effects of nicotine deprivation on craving response covariation in smokers. *J Abnorm Psychol*. 2003; 112:110–118. [PubMed: 12653419]

Figure 1.
Average self-reported craving (scale of 1-7) for deprived and non-deprived conditions by stimulus type and probability.

Figure 2. Skin conductance deviations for deprived and non-deprived conditions by stimulus type and probability during the four seconds prior to attempting to open the door.

Table 1
Means and Standard Deviations (in parentheses) for Negative and Positive Mood Ratings
at the 0%, 50% and 100% Cigarette and Water Trials

Negative Mood Rating			
	Probability		
	0%	50%	100%
Stimulus			
Cigarette	3.34 (1.68)	3.09 (1.53)	2.60 (1.39)
Water	3.13 (1.57)	3.02 (1.56)	3.08 (1.61)
Positive Mood Rating			
	Probability		
	0%	50%	100%
Stimulus			
Cigarette	3.98 (1.62)	4.45 (1.48)	4.92 (1.49)
Water	4.23 (1.59)	4.27 (1.58)	4.23 (1.67)

Note. For each rating type, statistically significant cigarette/water differences at each probability level are shown in boldface.

Table 2
Means and Standard Deviations (in parentheses) for Latency to Open the Door (in msec)
at the 0%, 50% and 100% Cigarette and Water Trials for Each Group Condition

Non-Deprived Group			
	Probability		
	0%	50%	100%
Stimulus			
Cigarette	2298.7 (431.7)	2228.3 (545.9)	2123.7 (552.7)
Water	2240.7 (370.4)	2209.1 (414.5)	2157.0 (437.5)
Deprived Group			
	Probability		
	0%	50%	100%
Stimulus			
Cigarette	2224.9 (436.6)	1967.8 (401.1)	1920.5 (464.5)
Water	2171.1 (410.1)	2062.9 (401.9)	1947.3 (401.6)

Table 3

Correlations of Craving on 100% Probability Cigarette Trials with Negative Mood and Positive Mood on Cigarette Trials (at 0, 50 and 100% Probability) for Each Group Condition.

Mood/Cigarette Probability	Group	
	Deprived (n=51)	Non-Deprived (n=50)
Negative / 0%	.40**	.43**
Negative / 50%	.31*	.38**
Negative / 100%	.04	.23
Positive / 0%	-.33*	-.27
Positive / 50%	-.07	-.07
Positive / 100%	.14	.13

*
p < .05,

**
p < .01