

FACTORS PREDICTING SMOKING IN A LABORATORY-BASED SMOKING-
CHOICE TASK

by

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ABSTRACT OF THE THESIS

Factors predicting smoking in a laboratory-based smoking-choice task

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This study aimed to expand the current understanding of smoking maintenance mechanisms by examining how putative risk factors of relapse relate to a single behavioral smoking choice using a novel laboratory smoking-choice task. After 12 hours of nicotine deprivation, participants were exposed to smoking cues and given the choice between smoking up to two cigarettes in a 15-minute window or waiting and receiving four cigarettes after a delay of 45 minutes. This single behavioral choice was meant to model real-world choices to forgo the immediate gratification of smoking to achieve delayed benefits associated with abstinence. Greater nicotine dependence, higher impulsivity, and lower distress tolerance were hypothesized to predict earlier and more intensive smoking. Out of 35 participants, 26 chose to smoke with a median time to a first puff of 1.22 minutes (standard deviation=2.62 min, range=0.03-10.62 min). Survival analyses examined latency to first puff, and results indicated that greater pre-task craving and smoking more cigarettes per day were significantly related to smoking sooner in the

task. Greater behavioral disinhibition was a significant risk factor predicting shorter smoking latency in the first two minutes of the task, but not at a delay of more than two minutes. Lower distress tolerance (reporting greater regulation efforts to alleviate distress) was related to more puffs smoked during the task. This novel laboratory smoking-choice paradigm may be a useful laboratory analog for the choices smokers make during cessation attempts and may help identify factors that influence smoking lapses.

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Introduction

Tobacco use is the leading cause of preventable death and remains a large public health burden, yet an estimated 46.6 million U.S. adults continue to smoke cigarettes (Centers for Disease Control and Prevention, 2011). Even with the smoking cessation aids currently available, the majority of smokers who try to quit are unable to maintain abstinence. An estimated 45.3% (20.8 million) of current cigarette smokers attempt to quit for one day or more in any given year (Centers for Disease Control and Prevention, 2008), yet population studies suggest that fewer than 5% of smokers who quit for 24 hours are still smoke-free at three months or one year post-quit (Centers for Disease Control and Prevention, 2002; Fiore et al., 2008). In order to improve smoking cessation rates, it is important to identify factors that drive returns to smoking and develop treatments targeting these key risk factors.

The current study seeks to examine the validity of a novel laboratory smoking choice task and assess the contributions of putative risk factors for relapse on a real-time decision about smoking in this new task. This laboratory paradigm seeks to build on previous research examining craving and smoking topography responses in the laboratory and smoking lapse and relapse outcomes in smoking cessation attempts. This research examined the relations between putative risk factors including nicotine dependence, impulsivity, and low distress tolerance and smoking behavior in a smoking choice task. Relapses to smoking likely begin with a single choice or smoking incident. This study attempts to model such choices under controlled laboratory conditions. The study also seeks to identify factors that influence these decisions.

Previous research has demonstrated that exposure to cues associated with cigarettes and smoking can elicit strong urges to smoke and other markers of smoking motivation, such as increased negative mood, withdrawal symptoms, heart rate, and skin conductance (Bailey, Goedeker, & Tiffany, 2010; Carter & Tiffany, 1999; Niaura et al., 1999; Payne, Smith, Adams, & Diefenbach, 2006). There are many limitations to these extant laboratory-based cue-reactivity paradigms, however. The degree to which intermediate outcomes, such as urges to smoke, can effectively stand in for behavioral smoking responses is not clear. Just as intentions do not always predict behavior (e.g., Fishbein, 2008), urges may not always be acted upon by smokers. Indeed, cue-reactivity outcome measures, such as craving, are inconsistently related to an individual's likelihood of relapse (e.g., Niaura et al., 1999; Payne et al., 2006) or reported smoking heaviness for the day or week following cue exposure (e.g., Carpenter et al., 2009). In addition, many studies do not simultaneously pair the stimulus cue with the opportunity to smoke (e.g., Carpenter et al., 2009; Droungas, Ehrman, Childress, O'Brien, 1995), so it is difficult to determine how an individual's reactivity to the stimulus might relate to later smoking behavior. Lastly, although a few studies incorporate the opportunity to smoke in the presence of the stimulus (e.g., Bailey et al., 2010), participants in these studies could only smoke when instructed. Because this smoking behavior is not self-directed, it likely does not imitate the individual's normal smoking pattern. In order to model smoking choices in the laboratory effectively (i.e., in a way that is likely to predict important clinical outcomes of smoking cessation attempts), the laboratory paradigm should include a self-directed behavioral smoking choice.

This study aims to expand the current understanding of smoking maintenance mechanisms by examining a new laboratory model of smoking behavior and evaluating how the putative risk factors of nicotine dependence, impulsivity, and distress tolerance relate to a smoking choice. To quit smoking, a smoker must decide to forgo the immediate gratification of smoking to achieve the long-term benefits associated with abstinence. This study models real smoking decisions in a laboratory-based choice between an immediate smoking opportunity and a larger, delayed reward. The utility of a single laboratory choice paradigm in predicting behavior over time has been well-established. Specifically, an individual's inability to delay immediate gratification to obtain a larger reward later has been shown to predict important behavioral outcomes, such as later substance abuse (Wulfert, Block, Santa Ana, Rodriguez, & Colman, 2002) and impaired academic performance and social functioning over a decade later (e.g., Mischel, Shoda, & Peake, 1988; Mischel, Shoda, & Rodriguez, 1989). Likewise, a single choice to delay immediate gratification from smoking might relate to broader behavioral outcomes such as smoking maintenance and cessation outcomes. Smoking behavior in a laboratory model that serves as a proxy for real smoking decisions should also relate to known risk factors for relapse. Dimensions of nicotine dependence, impulsivity, and distress tolerance that increase the likelihood of relapse might also relate to a smoker's inability to delay gratification in this paradigm.

Nicotine dependence is a latent variable that is thought to drive smoking behavior, including smoking heaviness and smoking persistence (Bolt et al., 2009). Those high in nicotine dependence should be those who are most likely to smoke under conditions designed to elicit strong smoking motivation, such as during a period of nicotine

deprivation likely to induce craving and nicotine withdrawal distress. Individuals with higher levels of nicotine dependence may smoke more frequently to allay withdrawal or cravings, and, over time, this behavior may become more automatic. Consequently, greater nicotine dependence might be a vulnerability predicting an individual's inability to refrain from smoking, particularly when experiencing withdrawal or craving. In fact, research has demonstrated that individuals who report smoking more automatically, or report that smoking eases their distress, smoke more cigarettes per day and are at a greater risk for relapse than are other smokers (Piper et al., 2004, 2008b). Accordingly, individual differences in nicotine dependence levels can be used to index drug motivation and predict smoking in a laboratory choice paradigm designed to model relapse. Greater nicotine dependence should predict decreased ability to refrain from smoking in conditions that augment the momentary motivation to smoke.

Impulsivity is another variable likely to influence smoking choices in the lab and during cessation attempts. Smokers who are impulsive are likely to have particular difficulty engaging in the kind of self-regulation needed to refrain from smoking in the face of temptation, even when they are motivated to abstain. Those who are most likely to choose the immediate gratification of smoking over waiting for a larger delayed reward should be those who exhibit greater impaired decision making and behavioral disinhibition (de Wit, 2009). Based on cognitive-motivational theory, impulsivity can be considered a trait-like construct that reflects increased awareness of and emotional reactivity to reward cues (Finn, 2002). This theory posits that individuals with high levels of impulsivity are more reactive and have greater difficulty inhibiting their behavior in the presence of a rewarding stimulus compared to individuals with lower levels of

impulsivity (Finn, 2002; Newman, 1987). In line with this theory, research has demonstrated that people who are more impulsive tend to smoke (Baker, Johnson, & Bickel, 2003; Mitchell, 1999), smoke more (Spinella, 2002), report greater craving when nicotine-deprived (VanderVeen, Cohen, Cukrowicz, & Trotter, 2008), and return to smoking more quickly after abstinence (Bickel, Odum, & Madden, 1999; Dallery & Raiff, 2007) than do people who are less impulsive.

Individuals who are more impulsive may act more quickly on immediate opportunities to smoke than would others, and this presents a particular vulnerability during cessation attempts because smokers must exert cognitive control to refrain from smoking when presented with smoking-related stimuli or experiencing cravings. In fact, evidence suggests that this vulnerability is heightened during a state of nicotine deprivation. Research has demonstrated that highly impulsive individuals engage in even more impulsive decision-making when deprived than when they are not deprived (Field, Santarcangelo, Sumnall, Goudie, & Cole, 2006; Mitchell, 2004). Specifically, smokers were more likely to choose smaller immediate gains over future delayed rewards when nicotine-deprived than after smoking (Mitchell, 2004; Field et al., 2006). Research suggests impulsivity predicts heightened craving and cessation failure (Doran, Spring, McChargue, Pergadia, & Richmond, 2004; Vanderveen et al., 2008), but to our knowledge, there is no available research examining the relation between this putative risk factor and an actual smoking decision. If the proposed paradigm is a valid measure of real smoking decisions, it should help identify the time frame and conditions under which risk factors, like impulsivity, predict actual smoking behavior.

According to the reformulated negative reinforcement model of drug motivation, reduction of negative affect is another powerful motive to smoke (Baker, Piper, McCarthy, Majeskie, & Fiore, 2004). Smokers who are less able to tolerate the negative internal states of withdrawal, such as craving or negative affect, will likely have a more difficult time refraining from smoking, even when they are motivated to abstain. Indeed, during a cessation attempt, individuals who report more subjective withdrawal distress are at greater risk for relapse compared to individuals who are less distressed (e.g., Abrantes et al., 2008; Shiffman et al., 2007; Shiffman & Waters, 2004). Evidence also shows that smokers differentially experience and respond to this subjective distress (e.g., Brown et al., 2009; Brown, Lejuez, Kahler, & Strong, 2002). Smokers with low distress tolerance (i.e., a decreased ability to persist towards a goal when experiencing affective, physical, or psychological distress) should be more sensitive and reactive to withdrawal distress and more likely to try to avoid this by smoking. Failure to inhibit this avoidance behavior may be a central process underlying substance use maintenance (Richards, Daughers, Bornoalova, Brown, & Lejuez, 2010). Therefore, a smoker's perceived or actual ability to withstand aversive internal states is an important influence on smoking behavior (Leyro, Zvolensky, & Bernstein, 2010).

In support of this notion, research has shown that smokers with lower distress tolerance achieve shorter durations of abstinence (Brandon et al., 2003; Brown et al., 2002) and experience greater craving and increased lapse risk during a quit attempt (Abrantes et al., 2008; Brown et al., 2009), compared to those with greater distress tolerance. Furthermore, research suggests that, during the initial stages of cessation, smokers may have lower distress tolerance than usual. Bernstein, Trafton, Ilgen, and

Zvolensky (2008) found that physiological distress tolerance was significantly lower for smokers when they were nicotine-deprived than when non-deprived. Distress is likely to be especially motivating in the context of deprivation and therefore one's perceived ability to tolerate distress is likely to be predictive of lapse or relapse. Since low distress tolerance seems to be a risk factor for continued smoking behavior, this vulnerability should also relate to behavioral outcomes of a laboratory smoking-choice model if it is a valid proxy of real-world smoking decisions.

The aim of this study was to develop a valid paradigm for studying smoking choices that could be used in future, prospective studies of smokers trying to quit. I hypothesize that higher levels of nicotine dependence, greater impulsivity, and lower distress tolerance will predict reduced likelihood of refraining from smoking in the presence of a salient smoking cue and an immediate opportunity to smoke. Examining how these risk factors predict a single smoking choice may improve our understanding of relapse and help identify targets for intervention.

Method

Participants

Participants were adult volunteers ($N=35$) recruited from mass media outlets in central New Jersey. To be eligible for the study, participants had to be at least 18 years of age, able to read and write English, and report smoking at least 10 cigarettes per day for at least 6 months. Potential participants were excluded from the study on the basis of heart disease; severe or worsening angina; heart attack or heart surgery in the past three months; diagnosis or treatment of schizophrenia, psychosis, or bipolar disorder; plans to quit smoking in the next two months; current use of smoking cessation treatments; or

being pregnant or breastfeeding. Participants also had to be willing and able to refrain from smoking for 12 hours before the study visit.

Procedure

All study procedures were approved by an Institutional Review Board. Interested volunteers were screened for eligibility over the telephone. Eligible participants scheduled an office visit and were instructed to refrain from smoking for 12 hours prior to the visit. At the visit, researchers described the study in detail and obtained written informed consent from participants. Research staff verified adherence to the deprivation manipulation by measuring reported time since the last cigarette and obtaining two samples of expired breath level of carbon monoxide (CO), a biochemical marker of smoke exposure. A mean expired breath CO level below 10 parts per million (ppm) verified at least 12 hours of abstinence for a daily smoker (Javors, Hatch, & Lamb, 2004). Participant compensation for stopping smoking for 12 hours was pro-rated based on CO level, such that participants received the full \$30 bonus if their CO level was below 10 ppm, half the bonus (\$15) if their CO level was 11-20 ppm, and none of the bonus (\$0) if their CO level was above 20 ppm. Participants received \$20 for the two-hour study visit and had the chance to earn up to \$27.20 in bonus money based on performance on the computer tasks. Participants who did not qualify were advised to quit and referred to smoking cessation resources in the area and thanked for their time. Participants who were eligible for the experiment completed the measures described below. Additional measures were administered that were not included in the subsequent analyses (see Appendix).

Pre-Smoking Choice Task Measures

Brief Questionnaire of Smoking Urges (QSU; Tiffany & Drobes, 1991). Craving was assessed using the 10-item version of the Questionnaire of Smoking Urges. Items are rated on a scale from 1 (*strongly disagree*) to 7 (*strongly agree*) where higher scores indicate greater craving. Sample items include “I have a desire for a cigarette right now,” “If it were possible, I would probably smoke now,” and “I could control things better right now if I could smoke.” Research supports an overall latent structure of general craving with two lower-order factors of strong desire/intention to smoke and anticipation of relief from negative affect (Cox, Tiffany, & Christen, 2001). The full 10-item version has shown high internal consistency (Cronbach’s alphas=.87-.89) across different populations of smokers (Cox et al., 2001).

Distress Tolerance Scale. (DTS; Simons & Gaher, 2005). This is a 15-item questionnaire that measures the degree to which individuals believe the experience of negative affect is unbearable. Previous research supports a multidimensional structure consisting of a total score of distress tolerance and four subscales: willingness to *tolerate* emotional distress, subjective *appraisal* of distress, attention being *absorbed* by negative emotions, and *regulation* efforts to alleviate distress (Leyro et al., 2010). Items are rated on a 5-point scale from 1 (*strongly agree*) to 5 (*strongly disagree*). Total scores range from 15-75 with higher scores indicating greater distress tolerance (i.e., less reactivity to distress). The DTS shows good internal consistency (DTS total Cronbach’s alpha=.91, subscale alphas=.66-.83) and validity in cigarette smokers (Leyro et al., 2010).

Breath-Holding Challenge. This is widely used as a behavioral index of distress tolerance (e.g., Brown et al., 2002; MacPherson, Stipelman, Duplinsky, Brown, & Lejuez, 2008). During this task, participants are instructed to take a deep breath and hold

it for as long as they can. They are asked to raise their hand to notify the experimenter when they begin to feel uncomfortable. The participants are instructed to continue holding their breath beyond the point of initial discomfort for as long as possible. Distress tolerance is measured as the latency in seconds between the point at which the participant begins to feel uncomfortable and the point at which they finally exhale. Due to non-normality in the distribution of distressed breath holding duration that was not correctible via transformation, this variable was re-coded into a binary variable using a median split (less than or equal to 6.5 seconds=0, greater than 6.5 seconds=1).

Delay Discounting. Delay discounting is the tendency to view rewards available at a later time as less valuable than those available sooner. In this computer-based delay discounting task, participants were presented with a series of choices between a smaller monetary reward available immediately and a large amount available later (e.g., \$10 today vs. \$20 in one week). A total of up to 300 questions was administered to assess discounting of rewards of \$20, \$100, and \$2500 at delays of 7, 30, and 180 days. Each series of delay discounting questions began with a randomly selected smaller, immediate reward in 2% increments of the larger, delayed reward (i.e., in multiples of \$2 when the delayed reward was \$100). The subsequent values of the smaller, immediate rewards in each series were calculated according to the algorithm described by Johnson and Bickel (2002). Briefly, each choice selected by the participant reset boundary levels representing the lower and upper limits of the participant's indifference point, the amount of money to be received immediately that was preferred equally to the delayed amount. The questions in the series continued (up to 50 individual items) until the difference between the outer upper and lower limits was within 2% of the magnitude of the delayed reward (i.e., the

questions ended for a \$100 series when the upper and lower limits of the participant's indifference point differed by only \$2).

Participants' delay discounting rates were calculated using the formula: $k=1/D[V_d/(V_p-1)]$, where k reflects the rate at which delayed rewards are devalued for each day of delay, D is the delay in days, V_d is the value of the delayed reward in dollars, and V_p is the value of the immediately available, smaller reward in dollars (Johnson & Bickel, 2002). To enhance motivation and attention to the choices, participants were informed at the beginning of the task that one of their choices would be treated as real and they would receive the monetary reward at the delay specified. One choice was randomly selected as a bonus payment for each participant (up to \$20).

Modified Conners' Continuous Performance Task-II (CPT-II: Conners, 2004; Conners, 1985). This is a computerized task designed to measure sustained attention and the ability to inhibit prepotent responses. In this task, the participant was instructed to press a key every time a letter appeared on a computer screen, except when the letter was an "X". On each trial, a single letter was presented in the center of the screen for 250 ms, followed by a variable inter-trial interval of 1, 2, or 4 seconds. The version of the task administered in this study differed from the Conners' CPT-II in that trials with varying inter-trial intervals were interspersed rather than blocked. To enhance participant motivation and effort on the task, participants were provided with feedback about their responses (in terms of accuracy) and were paid a bonus of up to \$7.20 according to their performance (\$0.02 per correct response on each of 360 trials). Responses were screened for inattention, whereby participant data was excluded when omission errors were greater than 5% in any block. Percent of commission errors and mean reaction time served as

behavioral measures of disinhibition. The order of the Delay Discounting and CPT-II tasks was counterbalanced across participants.

Smoking Choice Task.

The investigator brought two cigarettes from the participant's preferred brand, an ashtray, and a lighter into the smoking chamber. The participants received the following instructions:

For part of this project, we want to understand what triggers the urge to smoke. We will now expose you to smoking cues and triggers. This is meant to be a situation where you feel the urge to smoke, and we want to see how long it takes until the urge to smoke overwhelms you. For this task, we will give you two cigarettes now. We want you to light this first cigarette as you normally would and hold it in the hand you normally smoke with. We will ask you to hold this lit cigarette until the urge to smoke overwhelms you. Wait as long as you can before you smoke, but when you feel the urge is overwhelming, then you may smoke as you normally would. We are going to ask you to sit here quietly, and we will be outside monitoring your safety. Again, the room is specially ventilated to allow smoking indoors. The smoke will escape directly through this vent to the outside of the building. You can smoke one or both cigarettes in the next 15 minutes. If you do not smoke during this period, we will give you 4 cigarettes to take with you at the end of the session, which will be in 45 minutes.

Subjects were instructed not to use cell phones or other distractions during this task. The investigator left the room and observed the participant using a webcam that recorded the participant's behavior. After the 15 minutes passed, the investigator returned to the room and removed the cigarettes and ashtray. Participants who did not smoke received the delayed reward at the end of the session 45 minutes later. Smoking behavior during the smoking choice task was coded by latency to a first puff, total number of puffs taken during the 15-minute smoking period, and duration of time spent smoking in the task. Two independent, trained coders rated videos of smoking behavior to assess each of these targets. Inter-rater agreement was analyzed and disagreements were adjudicated by a third rater (the author of this thesis). Based on previous research, latency to smoke can be

used as an index of drug-seeking behavior or smoking cue incentive salience (Berridge, 2007; Carter & Tiffany, 2001).

Post-Smoking Choice Task Measures

Smoking Choice Reactions. Immediately after the smoking choice task, participants completed a questionnaire assessing reasons for choosing to smoke or abstain and methods used to deal with urges to smoke during the task (i.e., “distracted myself”). The QSU-brief was then administered a second time, and change in urge intensity from pre- to post-task was calculated as a smoking outcome variable.

Smoking History Questionnaire (SHQ). Smoking history and current use patterns were assessed using a 20-item questionnaire. The SHQ has been successfully used in previous studies as a measure of smoking history (Brown et al., 2002; Zvolensky, Lejuez, Kahler, & Brown, 2004). Duration of past abstinence and number of past quit attempts were examined as predictors of smoking latency in the lab task. The categorical variable of duration of longest past abstinence was re-coded using a median split (less than or equal to 2 weeks=0, greater than 2 weeks=1).

Wisconsin Inventory of Smoking Dependence Motives (WISDM-68: Piper et al., 2004). This is a 68-item self-report measure designed to assess nicotine dependence motives on 13 dimensions. Items are rated on a 7-point scale anchored at 1 (*Not at all true of me*) and 7 (*Extremely true of me*), with higher scores indicating greater nicotine dependence. Each subscale has shown high internal consistency (Cronbach’s alphas >.87) (Piper et al., 2004). Based on previous research, a total nicotine dependence score was calculated by averaging scores on the four primary subscales of the WISDM (automaticity, loss of control, craving, tolerance) (Piper et al., 2008a). This measure has

shown positive relations with smoking variables including cigarettes smoked per day, CO level, and likelihood of relapse at the end of treatment (Piper et al. 2004; Piper et al. 2008b).

Barrett Impulsiveness Scale-11 (BIS-11; Patton, Stanford, & Barratt, 1995). This is a 30-item self-report questionnaire designed to assess behavioral impulsivity. Items are rated on a 4-point scale ranging from 1 (*rarely/never*) to 4 (*almost always/always*). Total scores on the BIS-11 range from 30 to 120 with scores over 72 indicating high impulsiveness (Stanford et al., 2009). The scale has shown good internal consistency (total scale Cronbach's $\alpha=.83$, subscale α s=.59-.74) and good test-retest reliability (total scale Spearman's $\rho=.83$, subscales .61-.72) (Stanford et al., 2009).

The Fagerström Test of Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991). The FTND was adapted from the Fagerström Tolerance Questionnaire (FTQ; Fagerström, & Schneider, 1989) as a continuous measure of physical nicotine dependence. Items include questions such as "how soon after you wake up do you smoke?" Cumulative scores on the six-item questionnaire range from zero to 10, with higher scores indicating greater levels of nicotine dependence. The FTND has shown fair internal consistency ($\alpha =.61$) (Heatherton et al., 1991), positive relations with smoking variables (e.g., salivary cotinine levels and withdrawal severity), and high degrees of test-retest reliability (Payne, Smith, McCracken, McSherry & Antony, 1994; Pomerleau, Carton, Lutzke, Flessland & Pomerleau, 1994).

Demographics. A brief demographic questionnaire was administered to characterize the sample in terms of age, sex, ethnicity, race, marital status, level of education, employment status, and household income.

Data Analysis

Descriptive analyses characterized the distribution of the primary independent variables of interest (nicotine dependence, impulsivity, distress tolerance) to ensure that they were continuously, normally distributed. The primary outcome of interest was smoking latency during the smoking choice task, defined as time from lighting the cigarette to the first puff.

Discrete-time survival methods were used to analyze how the variation in risk of smoking over time was influenced by relapse risk factors and smoking history variables, while controlling for baseline number of cigarettes smoked per day and demographic variables, such as gender. For those who did not smoke during the observation period, their cases were censored and survival time was set to the end of the data collection window (Curry, Marlatt, Peterson, & Lutton, 1988). Event status was coded as 1=smoked prior to termination time or 0=still abstinent at termination time. A predictor was retained in the model if it improved the overall goodness-of-fit of the model. The effects of the continuous predictors were displayed by plotting survivor functions using Kaplan-Meier graphs and estimating the median lifetime, the time at which half the sample had experienced the event (puffing) and half had not (Willett & Singer, 1993).

In addition, the proportionality assumption was tested by including statistical interactions between the multivariate predictors and time in the hazard model and visually examining the Kaplan-Meier graphs (Willett & Singer, 1993). When a proportionality violation was detected (i.e., a predictor had a more pronounced effect on the risk ratio at a specific point in time compared to other points in time), the time

interval was split to more accurately analyze the effect of the predictor on the risk ratio at a particular point in time.

Lastly, multivariate linear regression models were used to analyze the relationship between putative risk factors and continuous smoking outcome variables while controlling for number of cigarettes per day and demographic variables. Non-significant predictors were eliminated from the models.

Results

Table 1 presents a summary of sample characteristics.¹ Among the 35 study participants, 26 participants smoked during the task, while 9 participants abstained and received the later reward. Hours of nicotine deprivation prior to the task did not differ significantly between those who smoked ($M=13.80$, $SD=1.56$) and those who waited in the choice task ($M=15.38$, $SD=3.61$), $t(9.05)=1.27$, $p=.235$.

Descriptive statistics regarding the candidate predictors of smoking behavior are shown in Table 2. Of those who smoked in the task, median time to a first puff was 1.22 minutes (standard deviation=2.62min, range=0.03-10.62min), the number of total puffs varied from 6 to 49 ($M=17.96$, $SD=11.19$), and total time spent smoking ranged from 3.05 to 10.87 minutes ($M=6.33$, $SD=1.87$). Participants who chose to smoke in the task had significantly higher pre-task craving, $t(33)=-2.84$, $p=.008$, and smoked more cigarettes per day on average ($M=18.58$, $SD=6.42$) than those who waited for the delayed

1. Some of the subjects in this study had extremely high discounting rates which could be indicative of high impulsiveness or inattention to the task (i.e., always selecting the immediate reward option, even when it was extremely small). For these participants, the pattern of responding across tasks was closely examined for inattention. All analyses were repeated after excluding participants suspected of inattention ($n=3$), and the pattern of results remained the same. The complete sample of 35 smokers was used for the analyses presented here.

reward ($M=13.00$, $SD=6.48$), $t(33)=-2.24$, $p=.032$. Using a liberal alpha level for this exploratory work, the results also indicated that those who smoked in the task reported greater need to regulate distress (lower tolerance for distress), $t(32.978)=1.80$, $p=.081$, compared to those who abstained.

Descriptive statistics regarding the reported reasons for smoking or abstaining in the task are shown in Table 3. The most commonly selected reasons for choosing to smoke in the task included strong urges/craving to smoke, being bored, and wanting to smoke as much as possible before someday quitting. Smokers who chose to abstain in the task frequently indicated that cigarettes are expensive and free cigarettes would help or that they wanted to challenge themselves in the task.

Latency to First Puff (N=35)

A Cox regression analysis predicting latency to first puff indicated greater pre-task craving ($\beta=.04$, $p=.017$; 95% *CI Odds Ratio* 1.01-1.07), and smoking more cigarettes per day ($\beta=.08$, $p=.004$; 95% *CI Odds Ratio* 1.02-1.15), significantly predicted increased odds of smoking in the task. The median latency to first puff was significantly shorter for smokers reporting pre-task craving above the median (0.93 minutes) compared to those with pre-task craving below the median (10.62 minutes) (see Figure 1 for Kaplan-Meier survival graphs). Participants who reported smoking more than 15 cigarettes per day on average had a shorter median latency to first puff (0.66 minutes) compared to those who smoked 10-15 cigarettes per day (5.82 minutes) (see Figure 2 for Kaplan-Meier survival graphs).

A violation of the proportionality assumption was detected in the relation between percent commission errors on the CPT and time (see Figure 3). Consequently, the effect

of this predictor was analyzed in two separate time intervals. Greater behavioral disinhibition on the CPT predicted a significant increase in the odds of smoking in the first two minutes of the choice task ($\beta=.44$, $p=.025$; 95% *CI Odds Ratio* 1.06-2.28), but not in the remaining 13 minutes, ($\beta=.11$, $p=.461$; 95% *CI Odds Ratio* 0.83-1.50).

Other smoking history variables and putative risk factors for relapse were not significantly related to latency to first puff and were removed from the model. Median survival times were estimated for the remaining predictors to provide initial descriptive information about the potential range of magnitude of candidate effects in this choice task (Table 4).

Total Number of Puffs (n=26)

A linear regression predicting total number of puffs indicated that lower scores on the regulation subscale of distress tolerance (signifying lower tolerance and greater regulation efforts to alleviate distress) predicted more puffs taken ($\beta=-.44$, $t(24)=-2.46$, $p=.022$, $R^2=.201$). No other candidate predictors were significantly related to the number of puffs taken.

Time Spent Smoking (n=26) and Change in Craving (N=35)

A linear regression model yielded no significant predictors of total time spent smoking during the choice task. Once accounting for smoking choice during the task, none of the putative risk factors were significantly related to change in craving pre- to post-task.

Discussion

This study examined risk factors for smoking in a novel, laboratory-based smoking choice task designed to serve as a proxy for the kinds of choices smokers may

face during attempts to quit smoking. Preliminary results support the validity of the smoking-choice paradigm. For nicotine-deprived smokers, the choice between two cigarettes now and four later yielded variable smoking responses in the laboratory. Furthermore, choosing to smoke rather than abstain in the task was meaningfully related to pre-task craving and smoking heaviness. This supports the notion that the conditions of this laboratory smoking-choice task produced strong momentary motivation to smoke. These results suggest that the smoking-choice paradigm may serve as a useful analog for relapse in smokers attempting to quit and may facilitate the identification of proximal determinants of relapse that could be targeted in future interventions.

In the current sample, two of the hypothesized risk factors for relapse were predictive of latency to smoke during the smoking choice task. Specifically, greater craving and smoking heaviness predicted shorter smoking latencies. This is consistent with research identifying craving and smoking heaviness as risk factors related to early relapse (e.g., Killen & Fortmann, 1997). Experiencing greater craving before being exposed to the potent smoking trigger used in this task (lighting and holding one's preferred brand of cigarettes while surrounded by smoking accessories and images) predicted shorter latencies to taking a first puff from the cigarette. This is consistent with other evidence showing that evoked craving predicts smoking behavior (e.g., Carpenter et al., 2009) and suggests that drug motivation processes are relevant to the real-time smoking choices made by smokers in this choice paradigm. In addition, the fact that heavier smokers waited a significantly shorter period of time before puffing in this challenging task further supports the claim that behavior during this task is related to drug motivational processes associated with smoking heaviness.

The tendency to experience craving in the presence of smoking cues and to smoke heavily may reflect underlying nicotine dependence processes. Smoking heaviness, withdrawal severity, and relapse are all thought to be observable outcomes linked to latent nicotine dependence processes (Piper et al., 2008a). The explicit measures of nicotine dependence administered in this study were not significantly related to smoking behavior during the smoking choice task, however. This may reflect a lack of power to detect relations of small to medium magnitude in the present sample. Alternatively, this null result may indicate that the self-reported measures of nicotine dependence used in this study are not valid measures of the processes governing behavior in the smoking-choice task. The reason for the null findings cannot be determined in this study, however. Studies with greater power to detect dependence-behavior relations are needed to address this concern.

The results of this study also provided new information about the relation between impulsivity and real-time smoking behavior. The results indicated that greater behavioral disinhibition, as measured by commission error rate on a behavioral task, predicted greater smoking risk in the first two minutes of the smoking choice task. Interestingly, this form of impulsivity (having difficulty inhibiting prepotent responses) was only predictive of latency to puff at the beginning of the task, when the smoking trigger and opportunity were introduced. This has implications for smoking cessation attempts and suggests that individuals who show high behavioral disinhibition may have a more difficult time inhibiting the immediate impulse to smoke if presented with a salient smoking cue or opportunity than would less impulsive smokers. The speed of responding to stimuli (reaction time) was not predictive of smoking latency or other dimensions of

smoking behavior (e.g., number of puffs) in this task. As such, disinhibition may be the dimension of impulsivity that is most relevant to the processes governing smoking behavior in this novel smoking choice paradigm.

Impulsive decision making did not predict smoking latency or other dimensions of smoking behavior in the current task, contrary to expectations. Although the current task is an explicit choice paradigm pitting a smaller reward available sooner against a larger, delayed reward (with a minimal delay), the choices exhibited by smokers in this task were not significantly associated with similar choices regarding monetary rewards. Inspection of the data in this sample indicated that some of the average discounting values were extremely high (yielding values greater than one that suggest respondents viewed rewards delayed as little as one day as worthless or that respondents were not carefully considering the options before responding). Previous research has demonstrated that smokers are more impulsive and have steeper discounting rates when deprived from nicotine, versus non-deprived (Mitchell, 2004; Field et al., 2006). As such, it is possible that the extremely steep discounting rates observed in some of the subjects in this study reflect real and intense responses to the 12-hours of nicotine deprivation experienced by smokers (as confirmed by CO testing) prior to the study. It is also possible, however, that low distress tolerance or insufficient motivation led some respondents to disengage from the task and to provide invalid data. These possibilities can be explored in future research that incorporates additional manipulation and validity checks in study procedures and assessments. The lack of association between responses to cigarette and monetary rewards may also reflect differences in the processing of these types of rewards. Research has shown that smokers discount money and cigarettes at different rates and that the

difference in the processing of cigarette versus monetary rewards is greater in the context of 24-hour nicotine deprivation (Mitchell, 2004). It may be that the lack of association between monetary discounting rates and smoking behavior reflects a divergence in the decision-making processes tapped by the two tasks in the context of deprivation and craving.

Results also indicated that a greater need to regulate distress (lower tolerance for distress) differentiated those who smoked and abstained and predicted greater smoking heaviness in the task. The smoking-choice task in this study was designed to elicit strong motivation to smoke and competing motivation to abstain to obtain the reward of four cigarettes of one's preferred brand at the end of the session. As such, the task likely induces response conflict and some degree of frustration. To successfully achieve the goal of obtaining four (instead of two) cigarettes, subjects needed to tolerate the craving and frustration induced by the smoking-choice task. The observed association between a self-reported tendency to attempt to regulate (i.e., minimize or eliminate) negative emotions and actual smoking in the choice task supports the negative reinforcement model of drug motivation (Baker et al., 2004) that asserts that smokers who associate smoking with relief from affective distress are those most prone to heavy smoking and relapse. This is consistent with previous research indicating a significant relationship between low distress tolerance on the regulation subscale and number of cigarettes smoked daily (Leyro et al., 2010). The fact that smokers with lower distress tolerance smoked more puffs in this challenging task supports the claim that behavior during this task is related to drug motivational processes associated with affect regulation and relief of withdrawal distress.

There are several limitations to this current study. Due to the preliminary, exploratory nature of this study, the analyses were not corrected for family-wise error. In addition, the size of the sample was small. The statistical significance of the results should therefore be interpreted with caution; however, the results are informative in providing initial validity information about the laboratory smoking-choice task. The study did not assess the predictive validity of real-time behavior in the smoking-choice task, so the relation to future relapse during a cessation attempt is currently unknown. The results also failed to show relations between smoking during the task and proxies for cessation success such as longest duration of past quit attempt, perhaps due to the small size of the sample or undetected outliers. Additionally, study participants were not currently seeking treatment, so these results might not generalize to smokers currently motivated to quit or those who cannot maintain 12 hours of abstinence. Although efforts were made to advertise for study volunteers broadly in the community, the participants were predominantly male (74.3%) and many (23.5%) were current students, so the results might not generalize to other, community-based samples. Due to the limited power of this pilot sample, we were unable to examine the interactive effects of the purported risk factors on smoking behavior, yet this is an important area for future research. To date, research has not examined how these combined vulnerabilities might further reduce a smoker's ability to refrain from smoking when presented with a salient smoking cue or opportunity.

The current study provided initial validity data regarding a novel, behavioral smoking challenge. This laboratory model of a self-directed smoking choice addresses some of the limitations of previous laboratory cue-reactivity models (as described in

Perkins, 2012), and may be a promising new approach to investigate the relation between relapse risk factors and smoking behavior. Results supported the hypotheses that some dimensions of dependence (the tendency to experience craving when nicotine-deprived and to smoke heavily), impulsivity (behavioral disinhibition), and distress intolerance (feeling the need to regulate distressing emotions) were associated with real-time smoking behavior during a standardized choice task. Future research is needed to assess the predictive validity of the smoking-choice task and to identify the specific dimensions of dependence, impulsivity, and distress tolerance that are most closely related to real-time smoking in the face of smoking triggers and opportunities. Additional research is also needed to determine whether these risk factors have additive or interactive effects on real-time smoking, as well. Understanding how these vulnerability factors influence real smoking behavior might identify mechanisms of relapse that can be targets for future intervention studies.

Table 1

Demographics for the Final Sample of Participants (N=35)

<i>Variable</i>	<i>n</i>	<i>%</i>
Female participants	9	25.7%
Hispanic (n=34)	2	5.7%
Race		
White	25	71.4%
African American	7	20.0%
American Indian or Native American	1	2.9%
Other	2	5.7%
Education		
0-11 grades completed	1	2.9%
Grade 12 or GED	17	48.6%
College 1-3 years	14	40.0%
College 4 or more years	3	8.6%
Employment		
Employed for wages	15	42.9%
Self-employed	3	8.6%
Unemployed less than 1 year	4	11.8%
Unemployed more than 1 year	6	17.6%
Homemaker	1	2.9%
Student	8	23.5%
Retired	3	8.8%
Disabled	4	11.8%

<i>Variable</i>	<i>n</i>	<i>%</i>		
Income				
Less than \$10,000	9	25.7%		
\$10,000-\$19,999	9	25.7%		
\$20,000-\$24,999	2	5.7%		
\$25,000-\$34,999	4	11.4%		
\$35,000-\$49,999	3	8.6%		
\$50,000-74,999	4	11.4%		
\$75,000 or more	4	11.4%		
Marital Status				
Married	3	8.6%		
Divorced	2	5.7%		
Widowed	3	8.6%		
Separated	1	2.9%		
Never married	19	54.3%		
Not married but living with partner	7	20.0%		
	<i>M</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
Age	36.31	15.15	18	68
Cigarettes per day	17.14	6.80	10	30
No. of years smoked	18.80	13.83	2	52
No. of past quit attempts	3.06	2.46	0	10
FTND total	4.06	2.02	0	8
Hours since last cig	14.21	2.31	12	23
Expired CO reading (ppm)	6.60	2.78	0	14

Table 2

Descriptive Statistics for Putative Smoking Vulnerability Factors, by Smoking Choice

	<i>Smoked (n=26)</i>	<i>Abstained (n=9)</i>
<i>Variable</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Pre-Task Craving	48.50 (13.36)	33.33 (15.22)
Nicotine Dependence		
WISDM primary dependence score	4.46 (1.18)	3.72 (1.10)
Impulsivity		
Delay Discounting rate (<i>k</i>)	0.52 (1.00)	0.50 (1.00)
BIS total score	64.08 (10.21)	68.22 (7.71)
CPT percent commission errors	3.23 (2.06)	2.84 (1.94)
CPT correct trial reaction time (msec)	441.40 (70.72)	432.30 (53.58)
Distress Tolerance		
DTS total score	54.35 (10.91)	57.89 (7.99)
DTS tolerance subscale	10.77 (3.36)	12.00 (1.32)
DTS appraisal subscale	22.50 (3.80)	23.33 (3.50)
DTS absorption subscale	11.08 (2.78)	11.22 (2.68)
DTS regulation subscale	10.00 (3.26)	11.33 (1.12)
Distressed breath holding duration (sec)	13.62 (14.90)	20.97 (20.52)

Table 3

Reported Reasons for Smoking or Abstaining in the Choice Task

<i>Variable</i>	<i>Smoked (n=26)</i>	<i>Abstained (n=9)</i>
	<i>N (%)</i>	<i>N (%)</i>
Urge to smoke was strong	21 (80.8 %)	0
Bored	6 (23.1%)	0
Smoke as much as possible before quitting	5 (19.2%)	0
Cigs are expensive/free cigs would help	3 (11.5%)	4 (44.4%)
Wanted to challenge myself	2 (7.7%)	5 (55.6%)
No urge/craving	2 (7.7%)	0
Did not need cigs	0	2 (22.2%)
Felt pressured/embarrassed	0	0

Table 4

Median Survival Time Estimates

<i>Variable</i>	<i>Median</i>		<i>95% CI</i>
	<i>Survival</i>	<i>Std.</i>	
	<i>Time (min.)</i>	<i>Error</i>	
Smoking History			
Maximum abstinence > 2 weeks	1.50	0.57	0.38-2.62
Maximum abstinence ≤ 2 weeks	4.46	2.40	0.00-9.18
No. past quit attempts ≤ 2	1.83	0.55	0.76-2.90
No. past quit attempts > 2	1.80	0.83	0.18-3.42
Nicotine Dependence			
WISDM average > 4.213	1.02	0.53	0.00-2.06
WISDM average ≤ 4.213	4.86	3.91	0.00-12.53
Impulsivity			
BIS total > 67	1.80	0.07	1.66-1.94
BIS total ≤ 67	2.30	1.09	0.17-4.42
Delay Discounting average $k > 0.062$	1.80	0.80	0.23-3.36
Delay Discounting average $k \leq 0.062$	1.83	0.84	0.17-3.50
CPT % commission (first 2 minutes) > 2.5	0.28	0.02	0.24-0.33
CPT % commission (first 2 minutes) ≤ 2.5	1.02	0.40	0.24-1.79
CPT reaction time (msec) < 430	1.80	1.42	0.00-4.58
CPT reaction time (msec) > 430	1.83	0.56	0.72-2.94

<i>Variable</i>	<i>Median</i>		
	<i>Survival Time (min.)</i>	<i>Std. Error</i>	<i>95% CI</i>
Distress Tolerance			
^a DTS total \leq 56	1.50	0.62	0.29-2.71
^a DTS total $>$ 56	2.30	0.84	0.64-3.96
DTS regulation \leq 10	1.02	0.62	0.00-2.22
DTS regulation $>$ 10	5.82	5.73	0.00-17.04
Distressed Breath Holding $<$ 6.5 sec	1.43	0.76	0.00-2.91
Distressed Breath Holding $>$ 6.5 sec	2.60	1.53	0.00-5.60

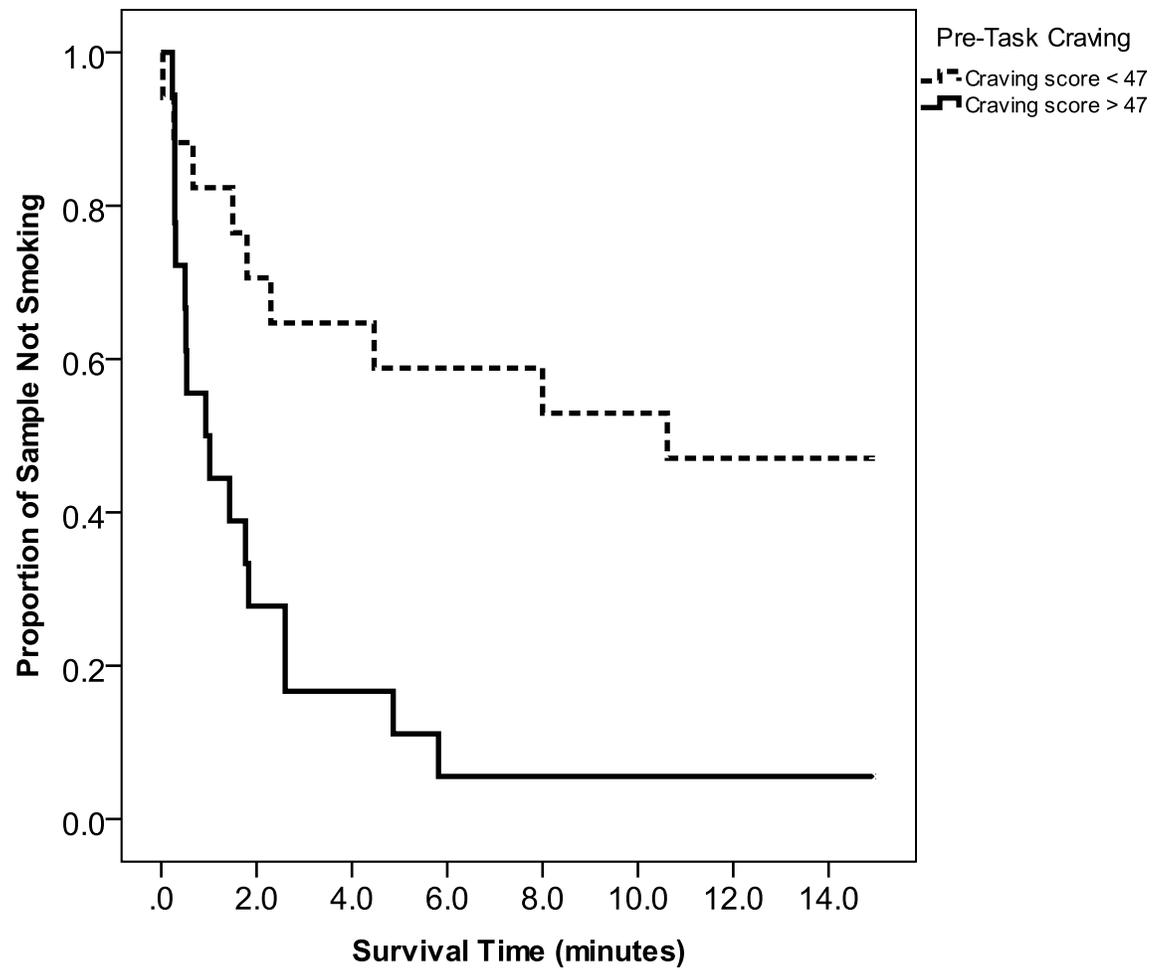
^a Survival times were estimated based on a median split for the DTS total score and four subscales. For three of the subscales, the results were identical to the DTS total score, so this information is presented once for economy.

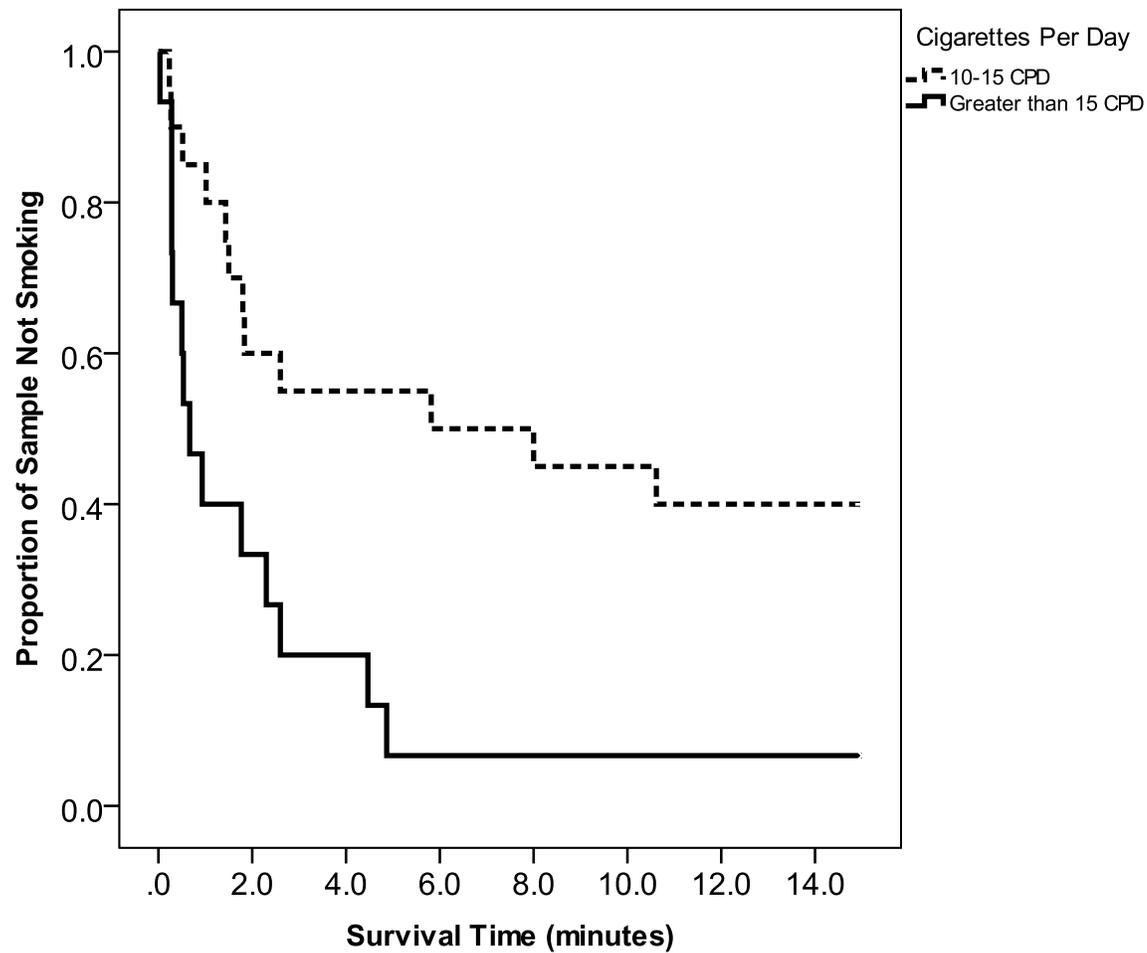
Figure Captions

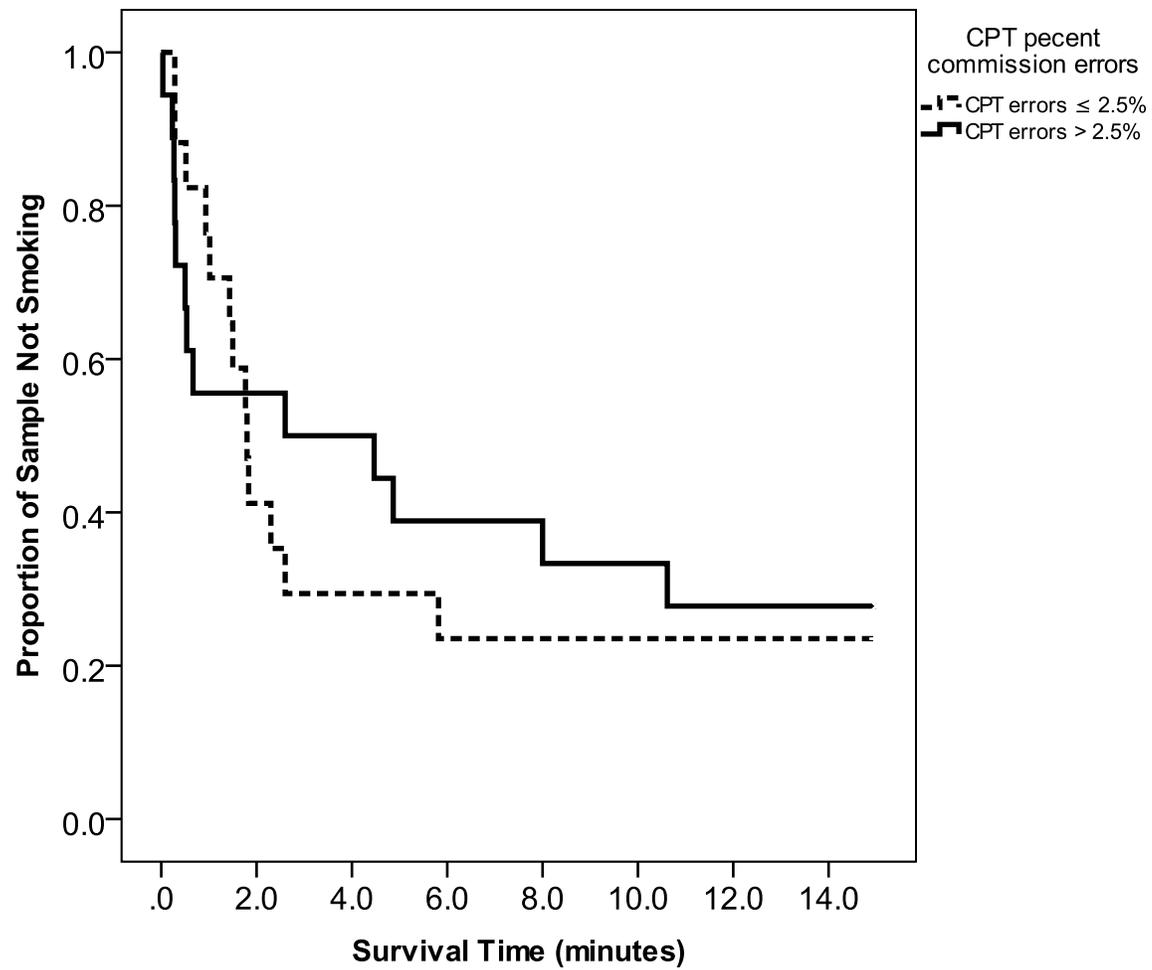
Figure 1. Survival curves for number of minutes to first puff for those with high vs. low pre-task craving.

Figure 2. Survival curves for number of minutes to first puff for those with high vs. low baseline smoking heaviness.

Figure 3. Survival curves for number of minutes to first puff for those with high vs. low commission error rates on the CPT.







Appendix

Additional measures that were administered in the study but were not discussed in this report include the following:

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1998). The PANAS consists of two 10-item mood scales designed to provide brief measures of current experiences of positive and negative affect. Participants responded on a 5-point scale from 1 (*very slightly or not at all*) to 5 (*extremely*) to indicate to what extent they were experiencing positive feelings such as “excited,” “strong,” “enthusiastic,” “alert,” and “inspired” or negative feelings such as “distressed,” “upset,” “scared,” “hostile,” and “ashamed.” Higher scores indicate stronger affect. These scales demonstrate high internal consistency (Positive scale Cronbach’s $\alpha=.89$, Negative scale $\alpha=.85$) and good validity related to clinical measures of mood and affect (Watson et al., 1998; Crawford & Henry, 2004).

Expectancies for Negative Affect Relief. This 6-item questionnaire is a variation of the Negative Affect Reduction subscale on the Smoking Consequences Questionnaire (SCQ; Copeland, Brandon, & Quinn, 1995) and measures the extent to which an individual believes that smoking a cigarette right now would reduce negative affect. This was not included in the analyses and will not be discussed further.

Delay Discounting. In addition to the two-option series, participants were presented with a series of choices between three monetary rewards (e.g., \$10 today vs. \$20 in one week vs. \$100 in two weeks). In the three option series, a total of up to 20 questions was administered to assess discounting of amounts of \$100 and \$1000 at a delay of up to 360 days. The choices in the series compared three rewards of increasing

value across three time delays (no delay, intermediate delay, large delay). The large delay was always twice the intermediate delay. The reward values were calculated using a similar adaptive heuristic algorithm to reset the lower and upper limits of the participant's indifference point based on the previous two answers. This new three option method was included to gather information about its validity.

Relapse Reaction Questionnaire. This is a 76-item measure designed to assess an individual's feelings and beliefs about their last failed quit attempt (or hypothetical quit attempt if a participant has never attempted abstinence). Sample items include "If I had to do it all over again, I would still have tried to quit," "I am sure I will quit smoking," and "I could deal with the loss of smoking." Items are rated on a scale from 1 (*disagree strongly*) to 7 (*agree strongly*) where higher scores indicate more resilient, positive reactions to relapse. This new measure was included to gather information about its psychometric properties and was administered during a participant waiting period.

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