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The Restorative Effects of Smoking upon Self-Control Resources

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by

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Abstract

Based on a model that considers self-control (SC) to be a limited resource, research suggests that diminished SC resources increase the likelihood of smoking. Yet, no study has evaluated how smoking affects SC resources. This study used a randomized, 2 x 2 crossed factorial (SC depletion manipulation X smoking manipulation), between-subjects design to test the hypothesis that smoking restores depleted SC resources. To manipulate SC depletion, half of the 132 dependent smokers were instructed to suppress their emotional reaction to a brief video depicting environmental damage (i.e., Depletion), whereas the other half were instructed to "act natural" (i.e., No Depletion) during viewing. Half of the participants in each condition then smoked a cigarette, whereas the other half sat patiently, without smoking (i.e., Smoke vs. No Smoke). All participants then completed two behavioral measures of SC (Mirror Tracing Performance Task: MTPT; and breath-holding). As hypothesized, a disordinal interaction occurred between the Depletion and Smoking manipulations for duration of time spent on the MTPT. That is, participants in the depletion condition showed less persistence on the MTPT, unless they were permitted to smoke. There was no evidence for mediation of this effect from the influence of smoking on affect and/or urge. Thus, smoking appeared to restore depleted SC resources, independent of its effects on self-reported affect and urge.

Findings suggest that restoration of SC resources may represent another form of negative reinforcement from smoking that may play a role in nicotine dependence, and could inform treatment development.

Introduction

Tobacco use is the leading preventable cause of mortality worldwide (World Health Organization, 2008), and is responsible for approximately $193 billion in annual medical expenses and lost productivity, nationally (CDC, 2008a). Despite these negative consequences, the adult smoking rate in the United States stands at 19.8% (CDC, 2008b). Although about 40% of these smokers attempt to quit each year (CDC, 2008b), only 4-7% succeed (Fiore et al., 2008). In addition to high relapse rates, there is evidence suggesting that the population of smokers is growing progressively more difficult to treat (Hughes & Brandon, 2003; Irvin & Brandon, 2000; Irvin, Hendricks, & Brandon, 2003). These findings exemplify the need to better understand the reinforcing properties of smoking (Perkins, Donny, & Caggiula, 1999). As these properties emerge, our conceptualization of nicotine dependence will become more refined, ultimately leading to more effective interventions.

Numerous models have been proffered to elucidate the mechanisms underlying nicotine dependence, including models informed by negative reinforcement (see Eissenberg, 2004), positive reinforcement (see Glautier, 2004), social learning, and cognitive theory (see Brandon, Herzog, Irvin, & Gwaltney, 2004). These theories may diverge on proposed mechanisms maintaining substance use, but they all view smoking as a learned behavior, and they need not to be viewed as mutually exclusive (Tiffany, Conklin, Shiffman, & Clayton, 2004). This study takes these models into account, with

particular emphasis on the role of negative reinforcement on the facilitation of smoking behavior. Specifically, we focus on the interrelationships of affect, self-control (SC), and addictive behaviors.

How affect is operationalized and measured can have profound impact on study design and interpretation of results (Kassel, Veilleux et al., 2007). Affect can be conceptualized broadly as a term superordinate to mood, emotion, stress, and impulses (see Gross & Thompson, 2007; Scherer, 1984). Affect regulation then, can be considered to include mood regulation, emotion regulation, coping, and defenses. Although affect is broad, affective state can be described in terms of two bipolar dimensions (see Barrett & Russell, 1998). That is, a subjective experience can fall within one of four quadrants, delineated by a valence (positive or negative) and activation (activated or deactivated). Kassel and colleagues highlight the importance of considering differential (and possibly orthogonal) roles of negative and positive affect (NA and PA). In fact, there is evidence to suggest that each of these have been found to have different neural underpinnings (Cacioppo & Gardner, 1999; Davidson, 1992), psychological correlates (Clark & Watson, 1988; Watson, Clark, & Carey, 1988; Watson, Clark, & Tellegen, 1988), and effects from nicotine (Cook, Spring, & McChargue, 2004; Cook, Spring, & McChargue, 2007). We contend that PA and NA can be independent, but they can also covary, depending on the level of activation and valence of each (Barrett & Russell, 1998).

Early accounts of negative reinforcement focused on the ability of substance use to ameliorate aversive withdrawal sympomatology, which then increased the likelihood of subsequent use (Jellinek, 1960, Wikler, 1948; Wikler, 1980). More recently, the influence of substance use on affective processing has been propagated as the prepotent

motive maintaining drug dependence (Baker, Piper, McCarthy, Majeskie, & Fiore, 2004). Baker and colleagues propose that through repeated drug use, initially aimed to alleviate the aversive withdrawal syndrome, an individual acquires NA as an interoceptive cue. Eventually, NA at levels outside of awareness may motivate consumption, in order to prevent it from reaching consciousness. Many other models of substance use also view affective regulation as central to continued use, again emphasizing the role of negative reinforcement (e.g., Khantzian, 1997; Wills & Shiffman, 1985).

In concordance with these models, a large proportion of dependent smokers endorse affect regulation as a primary motive for smoking (Copeland, Brandon, & Quinn, 1995; Ikard, Green, & Horn, 1969; Shiffman, 1993). Smokers hold strong outcome expectancies concerning the effects of smoking on NA (Brandon, Juliano, & Copeland, 1999), and in particular, the anxiolytic properties of smoking are reported as a contributing factor for maintenance (Frith, 1971; Spielberger, 1986). Additionally, desire to smoke, (Payne, Schare, Levis, & Colletti, 1991; Perkins & Grobe, 1992), smoking intensity (Cherek, 1985; C. S. Pomerleau & O. F. Pomerleau, 1987), and amount of consumption (Conklin & Perkins, 2005; Epstein & Collins, 1977; Rose, Ananda, & Jarvik, 1983; Schachter, Silverstein, & Perlick, 1977) have all been found to increase as a result of negative mood induction. These findings support the notion that NA may serve as an antecedent to smoking, and this is likely driven by the belief that smoking will alleviate NA.

Although NA appears to promote smoking behavior, and smokers believe consumption will attenuate NA, results have been less convergent as to whether smoking actually reduces NA that is unrelated to withdrawal (see Kassel, Stroud, & Paronis, 2003). It has been suggested that smoking may only ameliorate withdrawal-induced NA, and that smokers have generalized this, leading to expectancies of relief from NA produced by external stressors (Baker et al., 2004; Parrott, 1999). These expectancies have an impact though, as past research shows that smokers' expectancies moderate the effect of smoking on NA reduction from external stressors (Juliano & Brandon, 2002). Nonetheless, why smokers have these strong expectancies remains largely unanswered, and the failure to find a robust effect of smoking on NA may in part be due to disparity in research methodology (Baker, Brandon, & Chassin, 2004), the influence of moderators (Kassel et al, 2003), and situation-specificity (Perkins, Karelitz, Conklin, Sayette, & Giedgowd, 2010).

Self-Regulation and Self-Control Theory

The self-regulation literature may be useful for elucidating the relationship between NA and smoking. Self-regulation, as defined by Baumeister (2002), is a broad term referring to any effort by an organism to alter its own responses, and encompasses both conscious and unconscious processes. Self-control (SC) is a term often used interchangeably with self-regulation, but those who make a distinction consider SC to be a subset of self-regulation, referring only to the conscious, deliberate, and effortful ability to manipulate one's own responses (Baumeister, Vohs, & Tice, 2007).

Self-Regulation Failure. Numerous behavioral and impulse-control problems have been linked to self-regulation failure, including: overeating, alcohol and drug abuse, crime and violence, overspending, sexually impulsive behavior, and smoking (Baumeister, Heatherton, & Tice, 1994). Self-regulation has been purported to fail as a result of underregulation or misregulation (Baumeister et al., 1994). The former concerns the failure to exert control over oneself, where as misregulation refers to employing a SC strategy, that has detrimental long term consequences. Both forms of failure appear to be exacerbated by NA (Tice & Bratslavsky, 2000).

In terms of misregulation, the priority hypothesis assumes that affect regulation takes priority over other forms of SC when someone is experiencing NA, even if this leads to behaviors that may be damaging to one's health (Tice, Baumeister, Zhang, Philippot, & Feldman, 2004). Experimentally manipulating emotional distress has been found to increase impulse behaviors (Tice, Bratslavsky, & Baumeister, 2001). Furthermore, when told that these behaviors would not modify their mood, participants no longer exhibited the increase of impulse behaviors. These findings suggest that emotional distress shifted priorities away from distal goals and toward the immediate present, thereby engaging in behaviors that may alleviate NA acutely (i.e., misregulation), and this can be altered by challenging expectancies concerning the capability of the behavior to alter affect. The impact of NA on smoking behavior, the influence of smoking outcome expectancies as a motive to smoke, and the ability to manipulate these expectancies (Copeland & Brandon, 2000), are all congruent with this account.

Efforts to cope with NA may also decrease limited resources, leaving one susceptible to underregulation. Muraven and Baumeister (2000) applied a muscle analogy to better clarify the concept of SC, and the occurrence of underregulation in particular. They suggested that SC resources are limited and can become fatigued, much in the same way that a muscle becomes fatigued following physical exertion. Further evaluation of this phenomenon led to the development of a SC energy model, which interprets SC as a limited psychological resource that is susceptible to depletion (Baumeister, 2002; Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Vohs, & Tice, 2007; Muraven & Baumeister, 2000; Muraven, Tice, & Baumeister, 1998). A recent meta-analysis (Hagger, Wood, Stiff, & Chatzisarantis, 2010), incorporating the findings from 83 studies, provide support for the Self-Control Strength Model (also known as the Ego Depletion Model). There was medium-to-large effect size ($d^+ = .62$; Cohen, 1988), with those that completed tasks requiring SC resources having reduced performance on subsequent SC tasks.

The dual task experimental paradigm employed to examine the SC Strength Model involves the comparison of two groups on a frustrating or discomforting task (e.g. impossible tracing task, unsolvable anagrams, cold pressor, or handgrip). These tasks are considered to require SC because participants must persist, despite the inclination to quit and escape the aversiveness of the task. Prior to completing this SC task, one group first completes an initial task thought to require SC (e.g. emotion suppression, resisting a tempting food, or thought suppression), whereas the other completes a comparable but benign task (e.g. acting naturally, resisting a non-tempting food, or completing math problems). Those who complete the initial SC task consistently perform worse on the

second task of SC (both performance and duration based); leading to the conclusion that SC has been depleted. Although participants in the SC condition may rate their task to be more effortful and tiring than those in the comparison condition, both report comparable affect and arousal ratings, indicating that SC performance differences can occur independent of emotional state or arousal (e.g., Muraven et al., 1998).

Distress Tolerance: Another Form of Self-Control? A line of research that coincides with the role of underregulation and smoking relapse, albeit stemming from an alternative conceptualization, concerns individual differences in the degree of tolerance to discomfort and distress (Brown, Lejuez, Kahler, Strong, & Zvolensky 2005). During a cessation attempt, individuals must concurrently deal with the physical and psychological discomfort of withdrawal (Hughes, Higgins, & Hatsukami, 1990). Utilizing breath-holding duration as an analogue to persevering through withdrawal (based on the rationale that both depend on the capacity to withstand discomfort) the earliest studies of this kind found that this biobehavioral index of persistence predicted smoking cessation outcome (Hajek, 1991; Hajek, Belcher, & Stapleton, 1987). Behavioral persistence towards a goal, in the face of affective discomfort has since been operationalized as distress tolerance (Brown et al., 2005). A similar construct, task persistence, deriving from a learning-based "learned industriousness theory" (Eisenberger, 1992), emphasizes the role of reinforcement history for effort and its impact on persisting on future effortful tasks. Both programs of research measure their respective constructs by persistence on psychological or physical challenge tasks (e.g. difficult mirror tracing task, nearly impossible anagrams, paced auditory serial addition test (PASAT), CO_2 challenge, and breath-holding), all of which are similar to those used within the SC Strength paradigm

because they require continued persistence in the face of frustration and discomfort. Collectively, these constructs have been found to differentiate smokers from nonsmokers (Quinn, Brandon, & Copeland, 1996) and to predict: duration of previous smoking and substance cessation attempts (Brown, Lejuez, Kahler, Strong, 2002); residential substance abuse treatment dropout rates (Daughters et al., 2005); and future smoking cessation outcome (Brandon et al., 2003). Also consistent with SC theory, distress tolerance has been found to be context-dependent, with 12-hour smoking deprivation leading to decreased breath-holding capacity (Bernstein, Trafton, Ilgen, & Zvolensky, 2008).

Effects of Urge on Self-Control Resources. Substance use as a type of underregulation, rather than misregulation, has received far more attention within the field of addiction (see Sayette, 2004). The emphasis on underregulation is likely a result of trying to understand the phenomenon of relapse. In the context of those trying to quit, self-regulation may be required to overcome desires to smoke, which may impair the capacity for future SC. Contrary to this notion is evidence from a study utilizing ecological momentary assessment (EMA) suggesting that resisting temptations to smoke served as a protective factor to lapse (O'Connell, Schwartz, & Shiffman, 2008). This may be explained by experimental evidence that SC expenditure may enhance SC performance within the same domain, but lead to deleterious effects in others (Dewitte, Bruyneel, & Geyskens, 2009). Consistent with this explanation, resisting the consumption of alcohol during in vivo alcohol cue exposure has been found to reduce performance on a handgrip and self-stopping task (Muraven & Shmueli, 2006), and suppressing the urge to drink has been found to intensify smoking behavior (Palfai, Colby, Monti, & Rohsenow, 1997). Thus, resisting smoking during a cessation attempt may lead to underregulation in other areas of life.

Effects of Self-Control Resources on Addictive Behaviors. In addition to the potential for NA and urge to undermine effective self-regulation, SC resources may independently influence substance use. For example, an EMA study found social drinkers to be more likely to violate self-imposed drinking limits on days when SC demands were high, and this effect remained after controlling for mood and urge (Muraven, Collins, Shiffman, & Paty, 2005). The SC Strength Model has been applied directly to evaluate the effect of SC depletion on substance use. A SC depletion task was found to increase alcohol consumption relative to a control task, among a sample of social drinkers who were motivated not to drink (Muraven, Collins, & Neinhaus, 2002). This effect occurred despite no group differences in mood, arousal, or frustration. To date, only one study has employed the typical SC model paradigm to evaluate the effects of SC depletion on smoking behavior (Shmueli & Prochaska, 2009). Although the SC depletion task had no impact on urge to smoke or withdrawal, it increased the likelihood of smoking. This finding suggests that depletion of SC resources may independently increase the motivation to smoke, possibly at a level that is outside of awareness.

Can Smoking Restore SC? Following the principles of reinforcement, depletion may serve as a discriminative stimulus for smoking. If smoking were to reduce the depletion effect, it would then be reinforced, increasing the likelihood of future engagement in the behavior. There is evidence that although SC is expendable, it can also be restored (Tice et al., 2004). PA and relaxation induction have been found to facilitate this replenishment (Tice, Baumeister, Shmueli, & Muraven, 2007; Smith, 2002; Tyler & Burns, 2008). The usual design for testing this parallels the original depletion paradigm described above. Participants engaged in an initial act of SC (i.e. depleted) or a

comparison condition (i.e. non-depleted), and then SC was measured on another, seemingly unrelated task. However, when a positive or relaxation mood induction was placed in between the two tasks, those that were depleted performed similar to those that were not. Because non-depleted participants who received PA did not outperform non-depleted participants who did not, it can be concluded that PA does not lead to broad SC improvement, but merely the restoration of depleted SC (Tice et al., 2007).

If smoking were to increase PA and/or relaxation it may serve to restore SC resources. Dependent smokers commonly have outcome expectancies that smoking will increase PA (Copeland et al., 1995), and relaxation has been reliably reported as a motive for smoking (Dozois, Farrow, & Miser, 1995; Ikard, Green, & Horn, 1969; McNeil, Jarvis, & West, 1987). Although smokers have strong beliefs that smoking will led to increases in PA, the actual effects of smoking on PA are less clear (Kassel, Evatt et al., 2007). Many theories do focus on positive reinforcement as the mechanism maintaining drug dependence (Robinson & Berridge, 1993; Stewart, de Wit, & Eikelboom, 1984). Findings concerning the positive hedonic effects from smoking have been equivocal (Gilbert, 1995), but evidence is accumulating that suggests nicotine can increase PA (Argue, 1973; Perkins et al., 2006; C. S. Pomerleau & O. F. Pomerleau, 1992; Warburton & Mancuso, 1998). However, studies typically focus on high activation PA (e.g., euphoria), leaving deactivated pleasant affect (e.g., relaxation, calmness) largely unexamined (e.g., Kassel, Evatt, et al., 2007).

Specific Aims

We have reviewed evidence that SC is a limited resource and that acts requiring SC will impair future SC performance (i.e., depletion). Negative affect appears to facilitate this depletion, commonly serves as an antecedent to smoking, and may be attenuated following consumption. Positive affect appears to restore depleted SC resources, and may be augmented by smoking. Additionally, depleted SC resources, independent of affect, may lead to increased substance use. Smoking following SC depletion might serve to restore SC resources to baseline levels, allowing smokers to cope more effectively with subsequent tasks requiring SC. Thus, the main goal of the proposed study is to test empirically the influence of smoking on SC resources. Using a 2 X 2 experimental design we were able to test this hypothesis, using a common SC depletion manipulation (emotional suppression) followed by a smoking manipulation.

Specific aim 1: To test if smoking can counteract the effects of self-control depletion. Given that emotional suppression should deplete SC resources, we hypothesized that participants in the emotional suppression (i.e., Depletion) condition would persist less on two SC tasks (nearly impossible mirror tracing and breath-holding) than those in an "act natural" comparison condition (i.e., No Depletion). However, we hypothesized that participants who were allowed to smoke would not show this depletion effect on the SC tasks, because smoking would restore SC. Our primary dependent variable was duration spent on the mirror tracing task (MTPT). Breath-holding was considered as a secondary dependent variable, as the depletion effect may dissipate quickly. Figure 1 illustrates the hypothesized results.

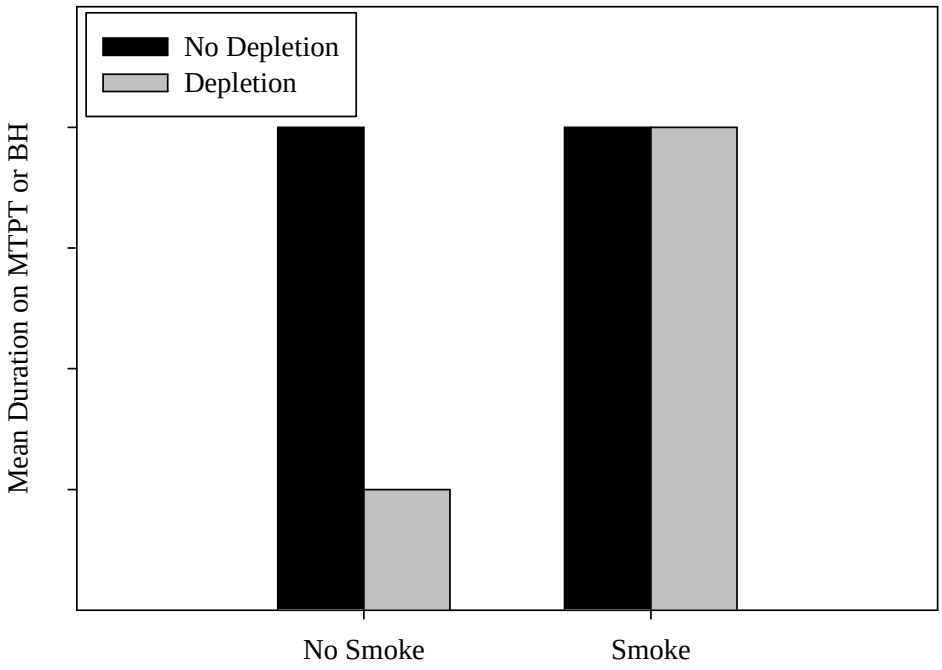

Figure 1. Hypothesized results.

Specific aim 2: To test the effects of smoking on affect. Although the effects of smoking on affect appear to have a strong influence on maintaining smoking behavior, the actual effects of smoking on affect have been equivocal. First, we hypothesized that those in the Smoking condition, compared to the No Smoking condition, would experience lower levels of NA, following the smoking manipulation. We also hypothesized that those in the Smoking condition, compared to the No Smoking condition, would experience higher levels of PA, following the smoking manipulation. We expect a similar pattern to emerge for deactivated pleasant affect (DPA).

Secondary aim 1: To test the effects of self-control depletion on motivation to smoke. To date, only one study has directly tested the influence of SC depletion on motivation to smoke (Shmueli & Prochaska, 2009). Although SC depletion was found to have no effect on self-reported urge to smoke in that study, we hypothesized that participants in the Depletion condition would report higher craving than those in the No Depletion condition, prior to the smoking manipulation. We also hypothesized that when given the opportunity to smoke, the Depletion condition would show patterns of smoking topography consistent with increased smoking motivation, as indexed by decreased latency to smoke and inter-puff interval, and increased # of puffs, puff volume, puff duration, and maximum flow rate (velocity) per puff, when compared to those in the No Depletion condition.

Secondary aim 2: To test the effects of self-control depletion on smoking satisfaction. Given that SC depletion may lead to more intense smoking topography and that smoking may be more reinforcing because it is paired with SC restoration, subjective ratings about the rewarding aspects of smoking may vary. We hypothesized that smoking would be more satisfying and psychologically rewarding, as indicated by self-report, for those in the Depletion condition compared to those in the No Depletion condition.

Secondary aim 3: To explore potential mediating and moderating variables for the restorative effects of smoking. Given that smoking may have effects on self-reported affect and urge to smoke, changes in these variables were tested as possible mediators, within the two depletion conditions (i.e. Smoke vs. No smoke), on the hypothesized effects of smoking on the SC tasks. Gender was explored as a potential moderator of the specific aims.

Method

Experimental Design

We employed a 2 X 2, crossed-factorial, between-subjects design to evaluate the interaction between SC depletion (via emotional suppression) and smoking. Participants were randomly assigned to one of four conditions (No Depletion + No Smoke, Depletion + No Smoke, No Depletion + Smoke, and Depletion + Smoke), stratified by gender (see figure 2). Dependent measures included time persisted on a near impossible mirror tracing task, breath-holding duration, self-reported affect and urge to smoke, smoking topography, and smoking satisfaction. Participants were compensated $25 for approximately 1.5 hours of their time.

		Self-Control Depletion (Emotional Suppression)	
		NO	YES
Smoking	NO	1	2
	YES	3	4

Figure 2. Study design.

Participants

The sample consisted of 132 smokers (50% female) recruited from the Tampa, Florida area, via newspaper and electronic advertisements. Power analyses demonstrated that this sample size provided a power of .81 to detect 'medium' sized main and interaction effects (Specific Aim 1), with a two-tailed alpha level of .05 (Cohen, 1988). Prospective participants were screened for the following inclusion criteria: English-speaking, between 18 and 65 years of age (M = 41.18; SD = 11.86), smoked at least 20 cigarettes per day (M = 24.06; SD = 6.50), began smoking 20 cigarettes daily at least one year ago, pre-session expired carbon monoxide (CO) concentration of at least 10 ppm (M = 35.31; SD = 19.58). Prospective participants were also screened for the following exclusion criteria: attempting to quit smoking (e.g. cutting down, enrolled in treatment, or using pharmacotherapy), pregnant, arthritis or any other condition that would prevent the full use of hands (e.g., paralysis), and hearing or visual impairment. Individuals who met all of the inclusion criteria and did not endorse any of the exclusion criteria were enrolled in the study. The sample was moderately to highly dependent on tobacco (M = 6.27; SD = 2.01), as indexed by the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991). Of the participants who indicated race and ethnicity (N = 130), the majority were Caucasian (78.5%), with 19.2% identifying as African American, 1.5% as American Indian or Alaskan Native, and .8% Native Hawaiian or other Pacific Islander. Of the sample, 13.8% were Hispanic or Latino.

Measures

Baseline characteristics.

Demographic questionnaire (DQ). The DQ is designed to assess basic information about participants, including: gender, age, marital status, ethnicity, race, educational level, and household income.

Smoking status questionnaire (SSQ). This measure assessed smoking history, current smoking status, and other smoking-related variables. Included in this measure is the Fagerström Test for Nicotine Dependence (FTND), which is a reliable and valid measure of nicotine dependence (Heatherton et al., 1991).

Exhaled carbon monoxide (CO). The measurement of exhaled CO level correlates closely with blood carboxyhaemoglobin concentration and provides an immediate, non-invasive method of assessing smoking status.

Balanced Inventory of Desirable Responding - Impression Management (BIDR-IM; Paulhus, Robinson, Shaver, & Wrightsman, 1991). The 20-item measure (α = .77) allowed for investigation of possible associations between impression management and all outcome variables. The dichotomous and continuous scoring methods produced similar results, so all subsequent analyses include continuous scoring of the BIDR-IM.

Depression, Anxiety, and Stress Scale (DASS-21; Antony et al., 1998). The DASS-21 is comprised of three subscales (Depression, Anxiety, and Stress), each containing 7 items and showing acceptable Cronbach's alphas (.94, .87, and .91). This measure has been found to be valid in clinical and non-clinical samples, and was used to assess trait dimensions of dysphoric mood (Depression), physical arousal (Stress), and psychological tension (Anxiety). The Depression and Anxiety subscales have shown concurrent validity with the widely used Beck Depression inventory (r =.79) and the Beck Anxiety Inventory (r =.85).

Manipulation checks.

Emotional suppression check (ES). This scale was used to assess the degree to which participants followed the Depletion manipulation instructions (i.e., emotional suppression vs. "act natural"). Participants indicated their agreement with 3 statements ("during the film, I tried not to feel anything at all," "during the film, I felt emotions, but tried to hide them," and "during the film, I reacted completely spontaneously") on a 7-point Likert-type scale. The last statement was reverse coded, and averaged with the other two to create an MC index (α = .84). These statements have previously been used to confirm the degree to which participants followed instructions (Gross, 1998a).

Task appraisal-1 (TA-1). Likert-type items assessed the degree of effort, difficulty, and fatigue experienced as a result of the depletion manipulation. For example, the effort item ranged from 0 (no effort at all) to 6 (extreme amount of effort). Scores on these items were average to create a TA-1 index (α = .85) assessing energy expenditure from the emotional suppression instructions. These appraisal items are commonly used, and the emotional suppression group should report higher scores than the comparison condition (e.g. Baumeister et al., 1998).

Specific aim 1: SC measures.

Mirror-Tracing Persistence Task (MTPT; Quinn et al.,1996). This measure served as the primary dependent outcome because it was the first SC task completed following the experimental manipulations, at which point the depletion effect was most likely to be present. This task is also more reliable, and less influenced by health status, in comparison to the secondary SC outcome. Participants were asked to trace geometric figures while viewing them through a mirror. Participants completed 5 trials. The first trial was relatively easy and served as a practice trial, at baseline. The second through fifth trials were extremely difficult and never successfully completed by participants. Participants were instructed to move on to the next trial when they had given up or after working on a figure for 5 minutes. The dependent measure was the mean time spent on all unsuccessfully completed trials. This task demonstrated high internal consistency (α = .93)

Breath-holding (BH). Due to previous research showing that the depletion effect is time limited (Tyler & Burns, 2008), this measure served as a secondary outcome. Participants were instructed to hold their breath for as long as they possibly could. Duration of breath-holding was timed with a stopwatch and used as a secondary dependent variable, measuring self-control.

Specific aim 2: Affect measures.

Mood Form (MF: Diener & Emmons, 1984). This measure contains 4 items that assess positive affect (α = .88-.92) and 5 items that assess negative affect (α = .84-.86). This measure was chosen for its brevity and ability to broadly assess each domain (as conceptualized by Barrett & Russell, 1998). Participants were asked how much they were currently experiencing each item using a 7-point scale ranging from "not at all" to "extremely much." This measure was administered at baseline, post-depletion manipulation, and post-smoking manipulation.

Deactivated pleasant affect (DPA). This measure was used to more comprehensively capture the effects of smoking on affect. The scale consists of 5 items that measured low activation pleasant affect (Barrett & Russell, 1998), and was integrated within the mood form. The scale displayed excellent reliability (α = .89-95).

Secondary aim 1: Motivation to smoke.

Urge to smoke (Urge: Kozlowski, Pillitteri, Sweeney, Whitfield, & Graham, 1996). This 3-item self-report measure was used to assess immediate urge or craving to smoke a cigarette (α = .88-.95). Participants were asked to use a 7-point scale ranging from "strongly disagree" to "strongly agree," for the following items: "I do want to smoke now," "I crave a cigarette right now," and "I have a desire for a cigarette right now." This measure was administered at baseline, post-depletion manipulation, and post-smoking manipulation.

Smoking topography. As behavioral index of smoking motivation, specific smoking behavior was recorded using the Clinical Research Support System (CReSS; Plowshare Technologies, Baltimore, MD). CReSS captured the number of puffs per cigarette, puff volume, puff duration, inter-puff interval, and maximum puff velocity. Participants smoked their usual brand cigarette through the CReSS mouthpiece, which has a small tube that connects to a pressure flow transducer. CReSS has been found as a reliable and valid assessment method of smoking topography in dependent smokers (Lee, Malson, Waters, Moolchan, & Pickworth, 2003). Data from the first puff and all puffs with volumes less than 12ml were excluded (all subsequent analyses showed similar patterns with these data included or excluded). Latency to first puff was coded independently by two trained raters (ICC = .97), from video obtained via a discreet digital video camera.

Secondary aim 2: Smoking satisfaction.

Modified Cigarette Evaluation Questionnaire (mCEQ; Cappelleri et al., 2007). The 12-item mCEQ is designed to assess the degree to which participants experience the reinforcing effects of smoking, including: Smoking Satisfaction (α = .86), Psychological Reward (α = .88), Aversion (α = .50), Enjoyment of Respiratory Tract Sensations (single item), and Craving Reduction (single item).

Exploratory analyses.

Distress Tolerance Scale (DTS; Simons & Gaher, 2005). This 14-item measure of general distress tolerance (α = .90) includes four subscales (Tolerance, Appraisal, Absorption, and Regulation). This measure has been found to be associated with alcohol problems and was examined here in relation to nicotine dependence, smoking topography, and persistence on the MTPT and BH tasks.

Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). This 10-item measure was used to assess individual differences in the habitual use of expressive suppression (α = .62) and cognitive reappraisal (α = .81). Scores were evaluated as possible moderators of the depletion effect.

Self-Control Scale-Brief (SCS-B; Tangney, Baumeister, & Boone, 2004). This 13-item measure was used to assess participants' trait level of self-control. Previous research has shown this measure to be a valid predictor on behavioral measures of self-control and it showed adequate internal consistency (α = .80). Analyses were conducted to see if scores on this measure moderated the depletion effect.

Smoking Consequences Questionnaire - Adult (SCQ-A; Copeland et al., 1995). Three of the 10 subscales were included in this study. The Negative Affect Reduction (α = .94), Stimulation/State Enhancement (α = .88), and Craving Reduction (α = .81) subscales demonstrated high internal consistency. Participants rated how likely or unlikely each statement was for them by circling a number on a 10-point scale ranging from 0 ("completely unlikely") to 9 ("completely likely"). Analyses were conducted to examine possible moderating effects of these scales on smoking topography, and with the effects of smoking on affect.

Task Persistence Self-Report (TPSP; Steinberg et al., 2007). This 2-item self-report measure of task persistence was used to assess participants' tendency to persist in effortful behavior. This measure did not demonstrate adequate reliability (α = .34), although it has in prior research (α = .73).

Task appraisal-2 (TA-2). Likert-type items assessed the degree of effort, difficulty, and fatigue experienced as a result of MTPT and BH tasks (similar to TA-1). Along with assessing how stressful and frustrating these tasks were, the measure allowed for the evaluation of how much participants tried on each of these tasks. This measure also allowed for comparisons to be made between the two SC tasks. These appraisal items are commonly used to evaluate how participants view stressful situations (e.g. Marlowe, 1998; Monroe & Kelley, 1997).

Manipulations

SC depletion. Emotional suppression has been defined as inhibition of emotion-expressive behavior while emotionally aroused (Gross & Levenson, 1993). Engaging in emotional suppression while watching a negatively valenced film is a typical manipulation used to deplete SC (Muraven et al., 1998; Vohs & Heatherton, 2000; Vohs & Schmeichel, 2003). This response-focused form of emotion regulation is commonly applied in everyday life (Gross et al., 2006), and although it is effective for inhibiting ongoing emotion-expressive behavior, it provides no relief from subjective effects of the emotion, and may come with cognitive and physiological costs (Gross & Levenson, 1993; Gross & Levenson, 1997; Richards & Gross, 2000).

All participants watched a 6 minute 11 second video clip from the film *Mondo Cane* (Jacopetti, 1961), depicting mutations and death of sea life. This was viewed on a laptop computer placed 2 feet in front of them. Prior to viewing, all participants were informed that they were about to watch a short film clip from an old documentary called *Mondo Cane,* showing some of the effects of the atomic bombs released during World War II. Everyone was told that they would be recorded while viewing the clip, and all participants were made aware of the location of the video camera during informed consent. Those in the Depletion condition were then instructed: “remain completely neutral on the inside and out. Please try your best not to let any feelings or responses you may have show on your face, and to the best of your ability, try to keep all of your internal reactions suppressed.” Participants in the No Depletion condition were instructed: “be as natural as possible, both on the inside and out. If you have any feelings or reactions to the movie, let them flow naturally.”

Smoking. All participants were told that the experimenter needed a few minutes to set-up for the next part of the study. Those in the Smoking condition were then given one of their usual brand cigarettes and asked to smoke using the CReSS machine. Participants in the No Smoking condition were asked to sit patiently until the experimenter returned. Following instruction delivery, the experimenter exited the room. Because of the limited duration of the depletion effect (Tyler & Burns, 2008), only 3 minutes was allocated for this manipulation.

Procedure

Potential participants were screened by trained operators. Those who qualified were instructed to bring a pack of their own cigarettes and to smoke one cigarette exactly one hour prior to their appointment and none thereafter. Figure 3 presents a timeline of the procedures.

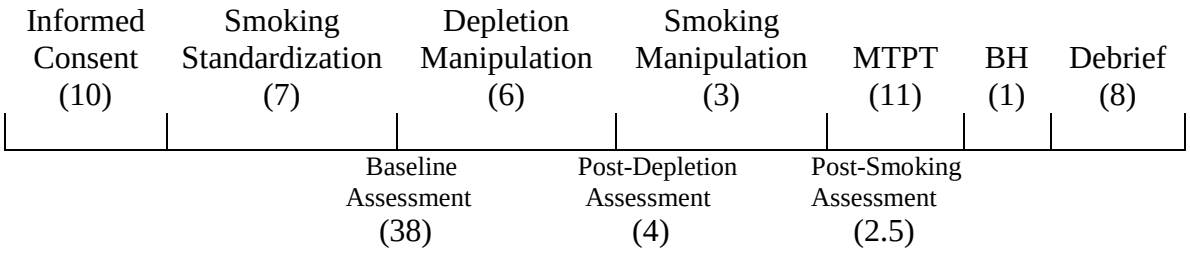

Figure 3. Schematic timeline of study procedures (with approximate duration, in minutes).

Upon arrival, informed consent and HIPAA authorization were obtained. Participants were then asked when they smoked their last cigarette and provided an expired air breath sample (to determine CO levels). Those reporting 45 minutes or greater since their last cigarette (75 minutes, on average) and meeting CO level eligibility then smoked one of their cigarettes using the CReSS machine. Along with standardizing smoking behavior, this procedure familiarized participants with the CReSS machine. After participants extinguished their cigarette, the experimenter collected their pack of cigarettes (to be returned at the end of the study) and administered baseline measures (DQ, SF, TPSR, DTS, SCS, SCQ-A, MTPT-1, ERQ, DASS, BIDR-IM, Urge-1, and MF-1). Upon completion of baseline measures, participants were randomly assigned to one of the four experimental conditions. Next, the Depletion manipulation was administered. Following the completion of the film, participants were asked to complete post-depletion manipulation measures of affect, urge to smoke, and the manipulation check (i.e. MF-2, Urge-2, ES, and TA-1). The smoking manipulation was administered immediately after participants completed the post-depletion manipulation measures (on average, 49 minutes from smoking standardization). Next, participants were asked to complete post-smoking manipulation measures (MF-3 and Urge-3). When participants were done with these measures, they completed the MTPT (began 9.5 minutes from the end of Depletion, on average). Following the MTPT, participants completed BH (approximately 26 minutes from the end of Depletion), TA-2, and those in the Smoke condition completed the mCEQ (approximately 30 minutes after smoking completion). Participants were then debriefed and compensated. To reduce demand effects, the experimenter was not present in the room while participants completed self-report measures.

Results

Preliminary Analyses

Baseline characteristics. Analyses of variances (ANOVAs) were used to verify that randomization led to equivalent group characteristics, and as expected there were no significant differences (all *p*s ≥ .09) across the four experimental conditions for demographic variables (DQ), nicotine dependence (FTND), urge to smoke (Urge), negative affect (MF-NA), positive affect (MF-PA), deactivated pleasant affect (DPA) and impression management (BIDR-IM). Also as expected, no differences were observed for number of attempts (*M* = 5.73; *SE* = 0.72) or time spent (*M* = 188.74; *SE* = 8.91) on the pre-manipulation MTPT practice trial (all *p*s ≥ .47).

Impression management. To test for potential bias due to demand effects, BIDR-IM scores were correlated with all administered measures (behavioral and self-report). No significant correlations were found between behavioral measures (MTPT, BH, and smoking topography) and BIDR-IM (all *p*s ≥ .10). Although no relationships were observed between BIDR-IM and self-report measures of manipulation check (ES and TA), and mCEQ (all *p*s ≥ .12), significant positive correlations emerged with PA and DPA (r's ranging from .23 to .35, all p's ≤ .008), and significant negative correlations occurred with NA and urge to smoke (r's ranging from -.19 to -.25, all p's ≤ .03). To correct for any potential bias, BIDR-IM was entered as a covariate on all analyses involving self-reported affect or urge to smoke.

Affect. To assess the interrelatedness of the self-reported measures of affect, correlational analyses were conducted between NA, PA, and DPA. NA was inversely correlated with PA and DPA at baseline, $r(130) = -.40$, $p < .001$; $r(130) = -.39$, $p < .001$, post-depletion, $r(130) = -.46$, $p < .001$; $r(130) = -.47$, $p < .001$, and post-smoking, $r(130) = -.37$, $p < .001$; $r(130) = -.38$, $p < .001$, but not to the degree that would suggest they represent a unitary construct. PA and DPA also covaried at baseline, $r(130) = .78$, $p < .001$, post-depletion, $r(130) = .71$, $p < .001$, and post-smoke $r(130) = .80$, $p < .001$. Although these correlations were high, all subsequent analyses were conducted on both scales because they were conceptualized as measuring distinct components of affective experience.

Depletion manipulation checks. To examine the degree to which Depletion manipulation instruction sets were followed, Analysis of variance (ANOVA) was conducted. As indexed by MC scores (possible score of 0-6), those in the Depletion conditions reported engaging in significantly higher levels of emotional suppression (M = 4.74; SE = .09) compared to those in the No Depletion conditions (M = 1.48; SE = .11), $F(1, 128) = 256.02$, $p < .001$, $f = 1.42$. Additionally, those asked to suppress their emotions (Depletion: M = 2.31; SE = .15) reported that following the assigned instruction set was significantly more effortful, difficult, and fatiguing compared to those asked to act naturally (No Depletion: M = .70; SE = .08), $F(1, 128) = 43.30$, $p < .001$, $f = .58$.

To validate that a depletion effect did in fact occur, only those in the No Smoke conditions (n = 66) were included in an ANOVA that examined the effect of the Depletion manipulation on MTPT. Replicating previous findings, those instructed to suppress their emotional reactions to the video (Depletion: M = 117.06; SE = 7.60)

persisted significantly less on the MTPT than did participants instructed to act naturally (No Depletion: M = 181.55; SE = 12.11), $F(1, 64) = 10.17$, $p = .002$, $f = .40$. However, breath-holding durations between the No Depletion *(*M = 51.73; SE = 4.60) and Depletion conditions (M = 51.62; SE = 4.60) were not significantly different ($p = .99$), thus a depletion effect was not apparent on this outcome variable. Consistent with prior literature on emotional suppression (and depletion manipulations more generally), the Depletion manipulation did not lead to subsequent differences on self-reported affect (all ps > .65).

Smoking manipulation check. Video data corroborated that none of the participants in the No Smoke conditions smoked and all of those in the Smoke condition did.

Primary Analyses

Specific aim 1: SC restoration. The hypothesized disordinal interaction of the manipulations on MTPT was tested via ANOVA. As predicted, neither Depletion (p = .08) nor Smoking had a main effect ($p = .12$), but as can be seen in Figure 4, there was the hypothesized significant Depletion x Smoking interaction [$F(1, 128) = 7.18$, $p = .008$, $f = .24$]. Post hoc Fisher's LSD tests revealed that MTPT was significantly lower for participants randomized to the Depletion + No Smoke condition, relative to each of the other three experimental conditions (all ps < .05). None of the remaining pairwise comparisons reached significance (see Table 1). However, there were no main effects or interaction for breath holding duration (all ps > .71). Thus, the Depletion manipulation led to decreased time spent completing the MTPT, but this depletion effect was mitigated by the Smoking manipulation.

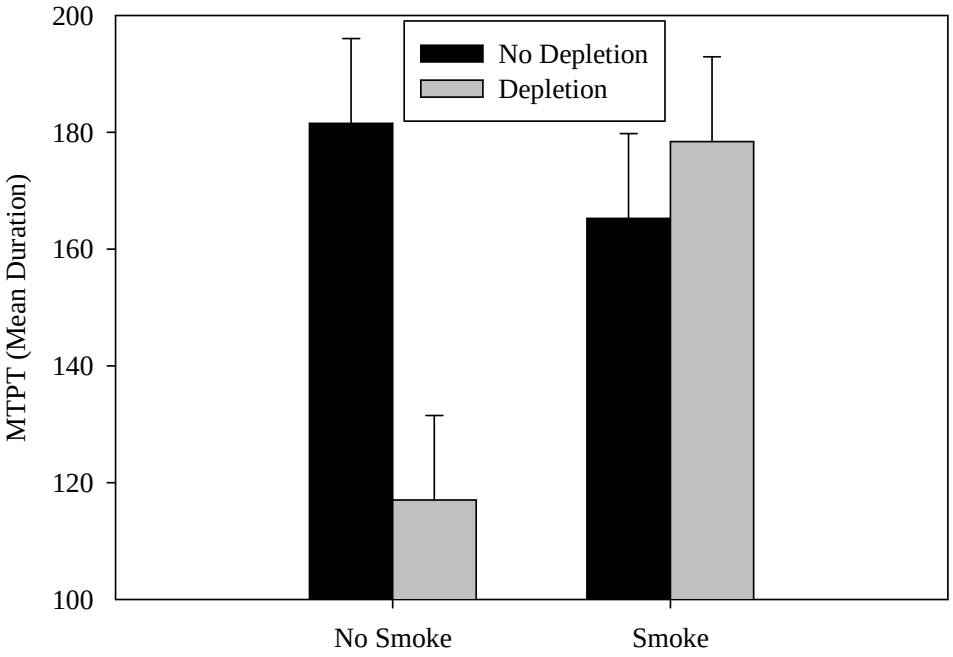

Figure 4. Mean duration on MTPT (and Standard Errors) as a function of the Depletion manipulation x Smoke manipulation interaction.

Specific aim 2: Affect. To examine the influence of Smoking on self-reported affect, separate ANCOVAs were conducted for post-smoking manipulation negative, positive, and deactivated pleasant affect (controlling for post-depletion and BIDR-IM scores). Consistent with our hypotheses, participants randomized to the Smoke conditions reported less negative affect *[F*(1, 126) = 3.94, *p* < .05, *f* = .18], more positive affect *[F*(1, 126) = 13.16, *p* < .001, *f* = .32], and higher levels of deactivated pleasant affect *[F*(1, 126) = 21.69, *p* < .001, *f* = .42], than their No Smoke counterparts (depicted in Figure 5 and Table 1).

There was also a main effect for the Depletion manipulation on NA, with No Depletion conditions (*M* = .81; *SE* = .09) reporting less NA compared to Depletion conditions (*M* = 1.07; *SE* = .09), $F(1, 126) = 4.18$, $p < .05$, $f = .18$. No significant interactions occurred between Smoke and Depletion manipulations (all *p*s > .54).

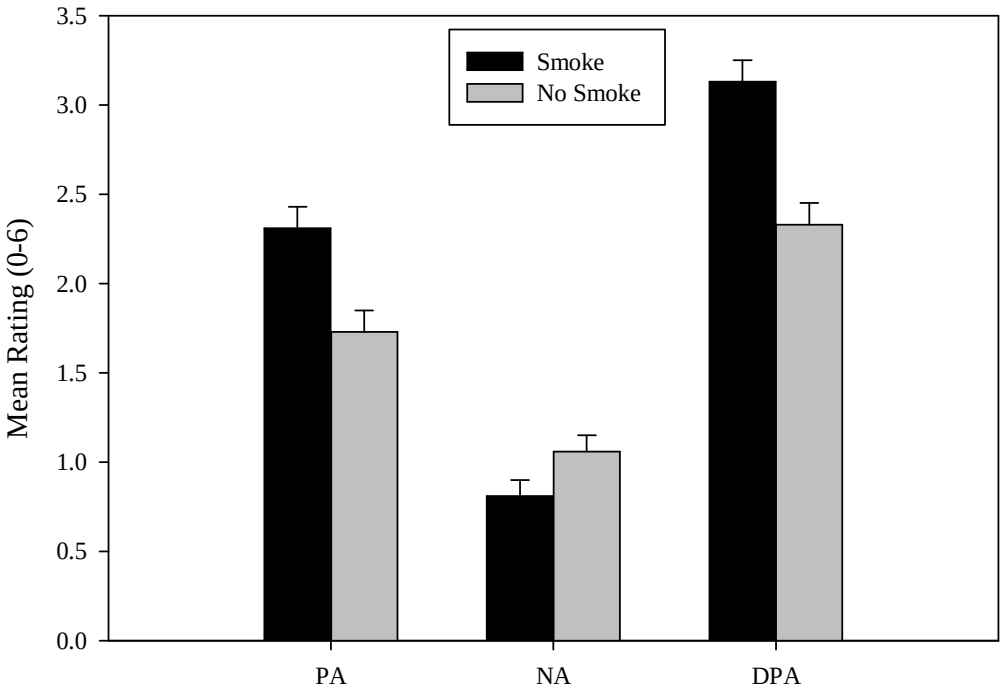

Figure 5. Covariate-adjusted (controlling for post-depletion and BIDR-IM scores) mean affect ratings (and standard errors) as a function of the Smoking manipulation main effects (Post-Smoke).

Table 1.

Means (Standard Errors) for Post-Smoking Manipulation Measures

	2 X 2 Condition Breakdown			
	(1) No Depletion + No Smoking	(2) Depletion + No Smoking	(3) No Depletion + Smoking	(4) Depletion + Smoking
MTPT	181.55 (14.49) [2]	117.06 (14.49) [1,3,4]	165.26 (14.49) [2]	178.43 (14.49) [2]
BH	51.73 (4.60)	51.62 (4.60)	52.20 (4.60)	54.54 (4.60)
NA	0.94 (0.13)	1.19 (0.13) [3]	0.67 (0.13) [2]	0.95 (0.13)
PA	1.91 (0.16) [3]	1.54 (0.16) [3,4]	2.40 (0.16) [1,2]	2.23 (0.16) [2]
DPA	2.39 (0.17) [3,4]	2.27 (0.17) [3,4]	3.19 (0.17) [1,2]	3.07 (0.17) [1,2]
Urge	3.72 (0.21) [3,4]	3.67 (0.21) [3,4]	0.40 (0.21) [1,2,4]	1.09 (0.22) [1,2,3]

Note. MTPT = duration of time (in seconds) until participants quit MTPT. BH = duration of time (in seconds) until participants quit holding their breath. NA = covariate-adjusted negative affect ratings derived from NA-3 mean score (controlling for post-manipulation NA= 1.49 and BIDR-IM = 3.72). PA = covariate-adjusted positive affect ratings derived from PA-3 mean score (controlling for post-manipulation PA= 1.56 and BIDR-IM = 3.72). DPA = covariate-adjusted deactivated positive affect ratings derived from DPA-3 mean score (controlling for post-manipulation DPA= 2.33 and BIDR-IM = 3.72). Urge = covariate-adjusted urge ratings derived from Urge-3 mean score (controlling for post-manipulation urge = 3.19 and BIDR-IM = 3.72). Superscript numbers indicate significant post hoc pairwise comparisons between the subscripted cell and the condition indicated by the subscript number (all *p*s < .05).

Secondary aim 1: Urge to smoke. To test the effect of the Depletion manipulation on self-reported urge to smoke, 2 X 2 ANCOVA was utilized (controlling for baseline urge and BIDR-IM scores). Analysis revealed no differences between Depletion conditions ($p > .16$), indicating that the Depletion manipulation did not influence post-depletion urge ratings. Unexpectedly, participants in the Smoke conditions had significantly lower post-depletion urge ratings ($M = 2.80$; $SE = .15$) than those in the No Smoke conditions ($M = 3.58$; $SE = .15$), $F(1, 126) = 14.67$, $p < .001$, $f = .34$, despite the fact that both conditions received identical experiences up to that point. As would be expected, this pattern also emerged for post-smoking urge ratings (Smoke: $M = .75$; $SE = .15$ vs. No Smoke: $M = 3.69$; $SE = .15$), $F(1, 126) = 187.95$, $p < .001$, $f = 1.22$.

Secondary aim 1: Smoking topography. Due to technical error, CReSS data from three participants were not captured. ANOVA was conducted on the remaining participants to examine the influence of the Depletion manipulation on latency to first puff. The effect of Depletion on the remaining topography variables were tested via ANCOVAs (controlling for baseline topography). Contrary to our hypotheses, no significant differences emerged between conditions (all *p*s > .20). Thus, the depletion effect manipulation had no impact on smoking topography.

Secondary aim 2: Smoking satisfaction. ANOVAs were conducted to test the effects of the Depletion manipulation on self-reported satisfaction, psychological reward, aversion, respiratory sensation, and craving reduction from the cigarette smoked during the Smoking manipulation ($n = 66$). No significant differences were found between conditions (all *p*s > .14). Thus, emotional suppression (Depletion) had no effect on the perception of pleasure/displeasure derived from smoking.

Secondary aim 3: Mediation. Exploratory analyses were conducted to determine whether SC restoration (on MTPT) produced by the smoking manipulation, was mediated by changes in affect and/or urge. Three standard tests of mediation were conducted: the Sobel (1982) test, the bootstrap approach (Efron & Tibshirani, 1993; Preacher & Hayes, 2004) and procedures as outlined by Baron and Kenny (1986). No evidence for mediation was found.

Additional Analyses

TA-2. Although there were no differences between conditions on how effortful, difficult, fatiguing, or frustrating the MTPT was perceived to be (all *p*s > .23), those in the No Smoke conditions (*M* = 4.32; *SE* = .24) reported the MTPT to be more stressful than those in the Smoke conditions (*M* = 3.49; *SE* = .24), $F(1, 128) = 5.92$, $p < .02$, $f = .21$. Additionally, Depletion conditions (*M* = 5.02; *SE* = .14) indicated that they did not try as hard on the MTPT as participants in the No Depletion conditions (*M* = 5.46; *SE* = .14), $F(1, 128) = 5.25$, $p < .02$, $f = .20$. Paired sample t-tests comparing appraisal rating between the two SC tasks (across conditions), found that MTPT was perceived to be more effortful, difficult, fatiguing, frustrating, and stressful than BH (all *p*s < .001).

Discussion

The main goal of the current study was to determine whether the SC depletion effect could be attenuated by smoking. The evaluation of smoking on SC resources was selected because of its potential to integrate findings within the addiction field concerning distress tolerance, learned industriousness, and affect regulation. Furthermore, understanding the relationship between SC resources and smoking may help to better inform theories of nicotine dependence and facilitate the development of new interventions for smoking cessation.

Effects of Smoking on Self-Control Resources

Our findings supported our hypothesis that smoking would have a restorative effect on depleted SC resources. To test this hypothesis it was essential that we could experimentally recreate a depletion effect. Participants randomized to the emotional suppression, compared to the "act natural" condition persisted less on a difficult and frustrating behavioral task (MTPT), thereby confirming that a depletion effect occurred. Those participants who were randomized to smoke prior to SC task initiation did not show this performance decrement, and they persisted as long as those who had not been depleted. Given that withdrawal effects can emerge rapidly (Hendricks, Ditre, Drobes, & Brandon, 2006), it was imperative to rule out withdrawal relief as the cause of smoking's apparent SC restorative effects. If withdrawal relief alone produces longer task persistence, we would expect to see this pattern within the No Depletion conditions.

However, there were no differences in task persistence between those who smoked compared to those who did not, so it appears that withdrawal relief did not account for this effect. It is important to note that smoking did not lead to broad improvements in SC resources-it only restored SC resources to pre-depletion levels.

The current findings support the conceptualization that the constructs of distress tolerance and task persistence may be context-sensitive; that is, influenced by both SC and smoking. This is consistent with a finding that smoking deprivation, when experimentally manipulated, led to decreased persistence on breath-holding, even after accounting for stress (Bernstein et al., 2008). The capacity to tolerate distress also appears to be compromised following engagement in tasks requiring SC (e.g., emotional suppression), and smoking can restore this capacity. As pointed out by Bernstein et al. (2008), research administering pre-quit measures of distress tolerance to prospectively predict outcome typically do so in a smoking-as-usual context (e.g., Brandon et al., 2003). It was suggested that administration should occur in contexts most similar to that experienced during a quit attempt, specifically a nicotine deprived state. Predictive power may also be increased by considering SC depletion state, as this is a context that will occur on occasion long after withdrawal symptoms subside. The process of relapse may also be better understood by evaluating SC resources during the actual quit attempt (via EMA), as a possible antecedent to lapse/relapse.

We were able to test our restoration hypothesis on only one of our behavioral persistence tasks because a depletion effect was only observed for the primary SC task (MTPT), and not the secondary SC task (BH).The former has been considered a psychological stressor while the latter has been thought to be more of a physical stressor.

However, it is unlikely that the domain of the task resulted in the differential efficacy of the depletion manipulation, as depletion effects have emerged on numerous physical tasks (e.g. cold pressor and handgrip). It may also be that BH was not stressful enough to evince a depletion effect, and, indeed, participants indicated that MTPT was more stressful than BH. The most plausible explanation for the lack of a depletion effect for the second behavioral task may be the limited duration of a depletion effect (Tyler & Burns, 2008). BH always occurred after MTPT, so not only was depletion time longer for BH than for MTPT (26 vs. 9.5 minutes, on average) it also differed as a function of MTPT performance. Alternatively, the MTPT task itself may have depleted SC resources, reducing the group differences in SC by the time of the BH task. Future studies may benefit by testing these hypotheses using a range of SC measures, at various post-depletion times.

Effects of Smoking on Affect

This study also aimed to evaluate the effects of smoking on different dimensions of affect. As hypothesized, we found that smoking resulted in higher levels of self-reported PA and DPA and lower levels of NA, compared to not smoking. It is apparent that smoking influenced participants' subjective experience; however, there are limitations to our findings. The study design compared only nicotine-deprived and nondeprived smokers, therefore we cannot differentiate whether smoking genuinely improved affect or simply reversed withdrawal. We are also unable to make inferences as to whether the pharmacological properties of nicotine or the behavioral components of smoking led to these differences. Systematically varying cigarette nicotine content and/or mood induction will likely led to a better understanding of the causal relationship

between smoking and affect (e.g., Perkins et al., 2008; Perkins et al., 2010; Conklin & Perkins, 2005). Additionally, Perkins and colleagues found that apparent affect modulation from smoking differs depending on the affect self-report measure used. This highlights the importance of having an a priori conceptualization of affect, in order to select appropriate study designs and measures most relevant to the research question at hand (Kassel et al., 2007). We chose the Mood Form (Diener & Emmons, 1984) because the descriptors of PA and NA broadly assess pleasant and unpleasant affect, across different levels of activation (see Barrett & Russell, 1998). More specifically, we aimed to evaluate the influence of smoking on deactivated pleasant descriptors (e.g., relaxed), because smokers hold strong smoking outcome expectancies concerning them and the effects of smoking on such descriptors has rarely been tested (e.g., Kassel, Evatt et al., 2007). In fact, smoking appeared to have the largest impact on deactivated pleasant affect (*ES* = .42 vs. PA: .32 and NA: .18), suggesting that it is an outcome deserving further research.

Possible Mediators of Self-Control Restoration from Smoking

Considering the evidence suggesting NA and urge to have deleterious and PA and relaxation to have restorative effects on SC resources, we examined if these factors mediated SC restoration from smoking. No evidence for mediation was found, as self-reported affect and urge were not predictive of persistence on the SC task. Thus, the current study suggests that smoking restored SC independent of its influence on affect and urge. By choosing brief measures of affect, we were unable to assess all possible affective domains (e.g., the PANAS could be used to capture high activation PA, which was not assessed here). This may have limited our ability to find a mediation effect.

Future studies may benefit from a more comprehensive assessment of self-reported affect, along with physiological and behavioral indices. As discussed by Kassel and colleagues (2007), addiction research may be aided by examining the effects of smoking on basic emotions (e.g., Ekman, 1984; Johnson-Laird & Oatley, 1992), rather than viewing affective experience in terms of two broad constructs (PA and NA).

The mechanism through which smoking restores SC was not delineated through this study, but the effects of smoking on numerous systems lead to a wide array of possibilities for future investigation. Executive control and SC resources have been shown to be highly related (Schmeichel, 2007), and smoking has been found to increase a variety of executive control indices (Evans & Drobes, 2009), so future research may benefit from evaluating some of these (e.g., working memory, attentional control, etc.) as potential mediators. A psychophysiological measure that may be informative is heart rate variability (HRV). HRV may serve as an index of SC resource strength, with increased HRV during tasks requiring high SC, and tonic levels predictive of SC task performance (Segerstrom & Nes, 2007). Increases in HRV have been observed for alcohol-dependent individuals who were able to resist consumption compared to those who could not, when exposed to alcohol cues (Ingjaldsson, Thayer, & Laberg, 2003). Although the acute and long term effects of smoking on HRV have been examined post-smoking (Hayono et al., 1990), no studies have evaluated HRV during smoking behavior, among non-abstinent smokers. Because smoking can alter respiratory rate (Jones, 1987) and fluctuations in respiration directly affects HRV (Bernston et al., 1997), it is likely that smoking would influence HRV.

Additionally, our design did not allow for us to differentiate whether nicotine was the responsible agent for smoking's restorative effect on SC, but placebo controlled designs could be used to parse the effects of nicotine and other smoking related factors.

Effects of Self-Control Depletion on Motivation to Smoke and Reward from Smoking

Although the primary hypotheses of the study were supported, none of the secondary hypotheses were. Prior to the smoking manipulation, we examined the impact of the depletion manipulation on self-reported urge. Consistent with the only other investigation of depletion on urge to smoke (Shmeuli & Prochaska, 2009), we found no differences between Depletion conditions. The current study utilized only a brief, 3-item, measure, which may have lacked sensitivity and precluded the multidimensional assessment of urge (Tiffany & Drobes, 1991). Shmeuli and Prochaska (2009) did find that Depletion predicted the likelihood of smoking, indicating that SC is associated with smoking motivation, and highlighting the need to measure the construct using verbal and nonverbal methods (see Sayette et al., 2000).

To evaluate whether motivation to smoke may be influenced by depleted resources at a level outside of consciousness, and therefore insensitive to self-report, we also incorporated behavioral measures of smoking topography. Again no differences emerged between Depletion conditions. By only allocating three minutes for the smoking manipulation we may have restricted variability in smoking behavior, thereby reducing the possibility of finding a depletion effect. It is also possible that the contrived smoking context of using the CReSS machine suppressed possible effects. Future research is warranted with participants smoking ad libitum.

In addition to smoking behavior, assessing changes in smoking motivation may better be detected through multidimensional, multi-modal approaches (e.g., psychophysiology, facial coding, neural substrates, etc.).

Additionally, we found that both Depletion conditions perceived smoking to be equally rewarding, as indexed by the mCEQ. However, it is difficult to draw a clear inference from this finding because this measure was administered approximately 30 minutes after smoking occurred, and therefore its validity may have been compromised. Administering the mCEQ directly following smoking behavior may lead to differential results on the reinforcing aspects of smoking, as a function of SC resource levels.

Theoretical Implications

The ability of smoking to remedy SC depletion strengthens the conceptualization that negative reinforcement is central to understanding nicotine dependence (Baker et al., 2004), while offering new mechanisms through which this might occur. Specifically, smoking may have been reinforced by ameliorating SC resource deficiencies, independent from its ability to modulate affect and urge. Although our study did not indicate that smoking was influenced by the depletion manipulation, other studies have provided evidence that depleted SC resources may serve as a discriminative stimulus, increasing smoking behavior independent of affect and urge (Palfai et al., 1997; Shmueli & Prochaska, 2009). This suggests that smoking may be used to regulate SC resources, with fluctuations of these resources serving as interoceptive cues indicating when to smoke. This could be a conscious decision, or it may be the case that smoking becomes an automatic form of self-regulation that does not require deliberate control (Mauss et al., 2007). Cognitive models of drug use have suggested that smoking can occur in such an

automatized form, with little expenditure of cognitive effort (Tiffany, 1990). Smoking may then allow for the allocation of SC resources towards affect regulation, thereby alleviating NA before it is experienced subjectively (Baker et al., 2004), or allowing for better tolerance for future stressors.

The latter explanation views smoking as an antecedent-focused regulation strategy, modifying internal context prior to the occurrence of an emotional response (Gross & Thompson, 2007). Consistent with this account is that participants who smoked found the MTPT to be less stressful than those who did not smoke. Most of the extent literature concerning the relationship between NA and smoking has instead viewed smoking as a response-focused strategy, used to regulate emotion following the occurrence of emotional response. This distinction may be critical for understanding the maintenance of nicotine dependence, as smokers may be attempting to modify future outcomes (Sayette, Loewenstein, Kirchner, & Travis, 2005), rather than react to the past.

Whether smoking is used to alleviate previous SC demands or to enhance the capacity to deal those to come, the capacity for smoking to restore SC can be viewed as a form of misregulation. Various forms of impulse behaviors have been described as misregulation, as they have been shown to increase when SC demands were higher (e.g., NA), resulting in priorities shifting toward proximal and away from distal goals (Tice et al., 2001). Perhaps SC demands are at the core of determining one's goal priorities, and smoking serves to regulate this relationship. Our findings are consistent with this account, because those who were depleted appeared to be focusing more proximally (e.g., escaping the aversiveness of the MTPT), unless permitted to smoke. Thus, the capacity of smoking to alleviate SC demands may bolster focus on distal priorities in other domains.

Future research may better explicate this hypothesis by examining the interrelationship of smoking and SC resources on decision making processes.

Treatment Implications

Considering that reinforcement from smoking may be a result of SC restoration that allows smokers to deal with subsequent tasks, cessation treatments may need to focus on providing them with other antecedent-focused strategies, thereby decreasing the risk of relapse. As suggested above, PA and relaxation are two promising areas. Interventions designed specifically to influence mood management have found that PA predicted cessation rates (Bränström, Penilla, Pérez-Stable, Muñoz, 2010). Although relaxation training is often incorporated within typical cessation treatments, we are unaware of smoking cessation treatments that rely solely on relaxation. When experimentally manipulated, controlled deep breathing has been found to reduce cravings, NA, and other withdrawal symptoms (McClernon et al., 2004). Glucose has also been found to restore SC resources (Galliot & Bauimester, 2007). Evidence also suggests that glucose may be a useful aid for smoking cessation (West, 2001), possibly more effective than NRT for short term abstinence (West & Willis, 1998). This is consistent with the current conceptualization that SC regulation is an underlying mechanism of nicotine dependence, as increasing levels of SC resources decreases the likelihood of relapse.

Research on distress tolerance has already aided in the development of a potential psychotherapy for smoking cessation (Brown et al., 2008). Utilizing Acceptance and Commitment and exposure-based techniques as adjuncts to typical cessation treatment, this new intervention aims to increase the capacity to tolerate discomfort. Evidence from the SC literature may also aid in the development of new treatments. Consistent with the

muscle analogy, SC can be strengthened through regular exercise of self-regulation (Baumeister et al., 2006). Thus, a behavioral intervention requiring repeated acts of SC in domains other than resisting urges could bolster SC capacity, increasing the likelihood of a successful quit attempt. This is convergent with learned industriousness theory, which posits that reinforcement for tolerating aversive tasks conditions reward value for effort expenditure, thereby reducing the aversiveness of high effort. Effort training (see Eisenberger, 1992) has yet to be tested experimentally as a form of smoking cessation treatment.

Conclusion

In summary, this was the first study to evaluate the effects of smoking on SC, and it appears that smoking can restore depleted SC resources. The capacity for smoking to restore SC occurred independent of its effects on self-reported affect and urge. Thus, the mechanism through which smoking acts on SC resources is yet to be determined, but may help to understand nicotine dependence, as the ability of smoking to restore SC resources may be conceptualized as a newly-identified form of negative reinforcement. Ultimately, it is our hope that what is learned through this experimental line of research will prove useful for developing more effective cessation interventions.

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