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Effects of smoking and nicotine withdrawal on prospective memory

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EFFECTS OF SMOKING AND NICOTINE WITHDRAWAL
ON PROSPECTIVE MEMORY

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TABLE OF CONTENTS

List of Tables

List of Figures

Abstract

Prospective memory (PM) refers to the ability to successfully remember an intention to be carried out in the future. The current study investigated the effects of cigarette smoking and nicotine withdrawal on PM. Smokers were randomly assigned to one of two conditions: nondeprived or deprived of nicotine for the 24-hours preceding the appointment. Nonsmokers were included for comparison. To mimic the experience of smokers during cessation attempts and to assess the potential additive effect of withdrawal, all smokers engaged in a cue reactivity task with the intent of increasing craving to comparable levels across the smoker groups. Despite equivalent use of memory strategies between groups, all 3 subscales of the self-report PM measure were significantly different between smokers and nonsmokers. Contrary to hypotheses, nondeprived smokers, not deprived smokers, demonstrated the lowest levels of PM across measures. As predicted, nonsmokers demonstrated the highest levels of PM performance across all measures. Withdrawal appeared to negatively influence lexical decisions and reaction times. Computerized PM performance did not correlate with self-reported everyday PM failures, and affect was related only to the self-report PM not the computerized tasks. Results suggest that PM impairment is related to smoking, but is not worsened by withdrawal, and point toward a potential mechanism through which coping response execution failures occur during cessation attempts.

Introduction

Relapse prevention is a major concern for recent exsmokers. Despite a desire to quit among 70% of smokers, few smokers are successful in permanently quitting (CDC, 2002). Current treatments for smoking cessation continue to demonstrate high relapse rates despite considerable attempts to improve the effectiveness of therapeutic programs. Long-term abstinence rates among exsmokers wanting to quit are low, ranging from 20 to 40% for treatment programs, and only 5% for those quitting without the aid of a treatment program (CDC, 2002; Hughes, Keely, & Naud, 2004; Shiffman et al., 1996; Stitzer, 1998). These remarkably high relapse rates among smokers are consistent with those for other substance use disorders. Success rates for smoking cessation treatments remain low even with various combinations of mood management, cessation skills training, contingency management, nicotine replacement therapy, and weight control treatment programs (Hall, Wasserman, & Havassay, 1991; Piasecki, 2006). Further, it appears that therapeutic effectiveness is decreasing over time in both pharmacological and psychosocial treatment trials for smoking cessation (Irvin & Brandon, 2000; Irvin, Hendricks, & Brandon, 2003), suggesting a trend for even greater difficulty in treating nicotine dependence.

To overcome the declines in success rates, treatments will need to identify and adapt improvements to facilitate therapeutic success. Attention has been given to the factors that may play a role in a smoker's commitment to change and persistence in successful abstinence, particularly the role of cognitive factors. Outcome expectancies (Brandon & Baker, 1991; Copeland, Brandon, & Quinn, 1995), change processes (Miller & Rollnick, 1995; DiClemente et al., 1991; Prochaska, Velicer, DiClemente, & Fava, 1998), and attentional biases (Ehrman et al., 2002; Ryan, 2002; Waters, Shiffman, Bradley, & Mogg, 2003; Waters, Shiffman,

Sayette, et al., 2003) have all received attention as possible mediating variables in the relapse process.

Current recommendations for treating smokers suggest a comprehensive approach, including pharmacological treatment in combination with cognitive and behavioral coping skills (USDHHS, 2000). The use of coping skills training is a common approach (Brandon, Vidrine, & Litvin, 2007; Hall et al., 1991), providing the smoker with skills to be applied as an environmental- or affect-related cue elicits an urge to smoke. Further, coping skills training typically provides resources for coping with generalized stress and negative affect. This is particularly important in consideration of models suggesting substance use becomes the primary means of coping for substance users over time (Wills & Shiffman, 1985).

Although coping skills utilization is predictive of successful abstinence (Haaga, 1989; Shiffman, 1982; Shiffman, 1984), a large portion of smokers fail to employ these skills (Brandon, Tiffany, Obremski, & Baker, 1990). The reasons behind coping skills failures are not fully understood (or haven't yet been identified). The present study tests a hypothesized mechanism through which coping skills failures may occur due to disruption in learning/memory processes during cessation.

Once a smoker has made the commitment to change his/her behavior (i.e., cessation of smoking), the commitment to quit, the reasons for quitting, and any coping skills for maintained abstinence must be remembered. When faced with a temptation to smoke, the smoker may fail to retrieve the needed information (i.e., being unable to retrieve a coping skill or access the memory of why quitting was important), will not cope adequately, and will therefore be more likely to relapse. Prospective memory (PM) has been proposed as a possible mechanism for this memory retrieval failure (Brandon, Herzog, Irvin, & Gwaltney, 2004).

However, surprisingly little research has been conducted with the PM construct in substance users.

PM refers to the memory of an intention to perform a task at some time in the future (McDaniel, Robinson-Riegler, & Einstein, 1998). For example, remembering to take a medication at lunchtime, remembering a doctor's appointment, or remembering to call one's colleague at 3 p.m. are all instances of PM. In the context of smoking cessation, a smoker must retrieve the intention to employ a coping skill when craving increases or when faced with other situations that are high risk for relapse. If withdrawal states impair a person's ability to retrieve this intention and thus the ability to follow through with the coping behavior, relapse would clearly be more likely. Craving has already been implicated as a cognitively demanding construct (Tiffany, 1990), but withdrawal may exacerbate these conditions leading to further difficulty in processing and executing new coping behaviors. Evidence suggests negative affect (a common withdrawal symptom and the most reliable predictor of relapse) impairs PM performance (Kliegel et al., 2005), providing support for the hypothesis that withdrawal will create additional limitations on cognitive resources.

Primary goals of the current study include 1) comparing smokers versus nonsmokers on PM tasks, and 2) investigating the impact of nicotine withdrawal on smokers' PM performance. The remainder of this paper will discuss the relevant literature in the areas of the relapse process and prospective memory. With the poor abstinence rates in treatment programs, expected growth trends in recalcitrant smokers, and the well known health consequences of continued smoking, improved treatment efficacy is necessary and timely.

The following discussion will begin by exploring possible reasons for high relapse rates among substance users, with a specific focus on nicotine dependence treatments. Following this introduction into relapse theories, the impact of withdrawal from substances

will be explored as a source of potential disruption to learning processes during treatment and/or cessation attempts. As one of the central therapeutic and didactic components within substance use treatment, coping skills training may be particularly vulnerable to learning/memory disruptions as they are often taught while smokers are in withdrawal. It is broadly hypothesized that learning disruptions would impact relapse rates through the failure to properly encode and retain information (i.e., coping skills) necessary for successful abstinence. PM is known to be impaired in substance users, including nicotine users. Nicotine withdrawal may cause further impairments in PM functioning, and thus may be a mechanism by which relapse occurs.

Literature Review

Relapse Process

Relapse, or use of a substance following cessation, remains a problem for drug users. A follow-up study of smokers' relapse patterns found that most relapses occur in the first three months following cessation (Brandon et al., 1990). Others have suggested that among self-quitters, the majority of relapses occur within the first week (Hughes et al., 2004). Smoking even one cigarette puts an individual at high risk for relapse. In the Brandon and colleagues (1990) study, 88% of participants who had even one cigarette post cessation relapsed during the two-year period studied. Perhaps even more worrisome, only 29% of the relapsers in this study reported using coping skills following post cessation cigarette use, despite the fact that 85% of participants received coping response skills training during treatment.

There has not been a standard definition of relapse in the literature, and the definition may vary according to type of drug and use patterns (Brandon et al., 2007; Hall et al., 1991). A distinction between a lapse and relapse has been made (Brownell, Marlatt, Lichtenstein, & Wilson, 1986), and can provide clinically useful information. Hall and associates (1991) identify three stages of the relapse process: (1) a lapse refers to the first use following cessation, (2) a lapse is distinct from return to continuous use, or relapse, and (3) the period between the lapse and full relapse is viewed as a separate and identifiable process. The distinction between slip and relapse is not always recognized in treatment programs. Programs such as Alcohol Anonymous, which advocate a 'one drink makes a drunk' philosophy, shape the lapse as a failure rather than merely a mistake or stumble on the path to sobriety. Such total abstinence models may foster perceptions of failure in individuals who use (e.g., lapse) any amount postcessation. The individual may then 'give up' and fully relapse- a behavior

consistent with the all-or-none philosophy he/she has learned. Rather, Marlatt (1985) presents the lapse in terms of a 'fork in the road', a choice of continuing to positive behavior change or toward the previous problem, emphasizing the role of personal choice. Beyond clinical applications, the distinction between lapses and relapses is an important consideration in research. Brandon et al. (2007) note that many studies continue to define relapse as 'any use' following cessation, and suggest that the reliance on this definition for evaluating treatment outcome may be overly severe. For example, average number of drinks per drinking episode or number of drinks per week provide far more information regarding the impact of treatment.

An emphasis of Marlatt's (1985) model is the role of the 'high risk situation' in relapse. A high-risk situation refers to a situation where an individual has ineffective (or perceived ineffective) coping skills for a situation where drug use is expected, or commonly occurred in the past. Examples differ from one individual to another, but common high-risk situations include social pressures (while drinking, being around drug-using friends), negative affect (anger, depression, anxiety) and interpersonal conflict. The effective use of coping skills during high-risk situations contributes to increasing the individual's self-efficacy and mastery for remaining drug-free, reducing likelihood of future relapse. Conversely, when encountering high-risk situations with ineffective coping skills, a reduction in self-efficacy is experienced along with a rise in positive expectancies (beliefs about the immediate positive consequences of drug use, i.e., alleviation of negative affect). Motivation to use the drug increases as positive expectancies outweigh negative expectancies, and a slip occurs.

In application to Marlatt's (1985) model, PM impairment may be a contributing factor to the inability to successfully apply coping skills in a high-risk situation. That is, if the individual cannot recall the intention to apply appropriate coping skills as needed (or the content of the intention), the likelihood of relapse and impaired self-efficacy increases.

Although the present study is not intended to address the specific aspect of the relapse process that is affected, significant results would suggest a possible mechanism underlying relapse.

Clearly, Marlatt's (1985) relapse prevention model emphasizes the role of cognitive and behavioral processes in relapse situations. This is consistent with the basic tenants of most cognitive-behavioral based cessation programs (McCusker, 2001), which emphasize skill deficits and focus to a large degree on behavioral and cognitive skills to promote abstinence.

Tiffany (1990) presents a view of drug-use behavior distinct from the cognitive-behavioral based and classical conditioning models. In his model, Tiffany (1990) stresses the involvement of both automatic and nonautomatic processes. With repeated practice, drug use behavior becomes an automatic process in the same manner as many other behaviors (i.e., typing; Tiffany & Carter, 1998). The cognitions involved in drug use behavior are largely outside of awareness and require little or no effort (Tiffany & Carter, 1998). Thus, due to their automatic nature, these cognitions will be inherently difficult to control (Tiffany & Carter, 1998) and not easily changed by traditional cognitive-behavioral techniques (McCusker, 2001). In his critique of current addictions methodology, McCusker (2001) emphasizes the need to address these automatic processes.

Tiffany's (1990) cognitive processing model rejects the traditional view of craving as a major explanatory factor in drug use. In contrast to classical conditioning conceptualizations where craving is central to the subsequent use of drugs, the cognitive processing model presents craving as a nonautomatic process that occurs when automatic processes are blocked (i.e., when access to drugs is not possible; Tiffany, 1990; Tiffany, 1995). Thus, the cognitive processing model accounts for occurrences of drug use that occur without craving, a situation that was difficult for the classical conditioning model to explain (Tiffany, 1995). Craving then requires effortful processing and may have an impact on other mental processes (Tiffany,

1999; Sayette & Hufford, 1994). If cognitive capacity is a limited resource, the concept that craving requires the devotion of cognitive resources suggests that other mental processes (such as PM or coping) have the potential to be impaired. While it is common for craving to increase during a withdrawal period, it is important to recognize the distinction between craving and withdrawal. Tiffany (1990) presents these concepts as distinct from one another, and as such they can occur independently. The distinction between withdrawal and craving has been reinforced with the removal of craving as one of the diagnostic criteria in recent editions of the Diagnostic and Statistical Manual for Mental Disorders (DSM; APA, 1987; 1994; see also Piasecki, 2006), suggesting withdrawal is not necessary for cravings to be produced. However, it is probably more common for craving to occur outside of withdrawal, than for withdrawal to occur unaccompanied by cravings. Indeed, while not listed as a diagnostic criterion, the DSM-IV notes that craving will most likely accompany withdrawal in nearly all cases (APA, 1994). Thus, many of Tiffany's (1990) predictions regarding the demands of craving on cognitive resources can be applied to withdrawal states. Others have noted the possible additive impact of withdrawal and craving (Mendrick et al., 2006; Sayette & Hufford, 1994), increasing the demands placed on smokers during cessation.

While support for Tiffany's (1990) cognitive processing model is far from equivocal (see Bradizza, Lisman, & Payne, 1995), several studies have shown evidence suggesting high craving states place demands on cognitive resources (Cepeda-Benito & Tiffany, 1996; Juliano & Brandon, 1998; MacKillop & Lisman, 2005; Sayette & Hufford, 1994). Further, associations between level of dependence and attentional biases suggest that higher dependence is characterized by automaticity consistent with Tiffany's (1990) predictions (Mogg, Field, & Bradley, 2005). Sayette & Hufford (1994) examined the independent effects of craving and withdrawal on reaction time, and found smokers respond more slowly in the

8

presence of a smoking cue regardless of deprivation state; however, a second experiment showed greater impairment in the deprived condition. Although not addressed in Tiffany's (1990) model, it is possible that the combination of craving and withdrawal create additive limitations on cognitive resources. Directly related to the current study, the authors hypothesize that reactions to cues in the environment may deplete limited cognitive resources, leaving fewer resources available to devote to coping (Sayette & Hufford, 1994). Additionally, there is tentative evidence that the impairments may be more important for encoding as opposed to retrieval processes (Heishman et al., 2006).

The assertions of Tiffany's (1990) model are relevant to the focus of the current study. Smokers in withdrawal would have nonautomatic processes engaged (craving induced via blocked access), limiting the cognitive resources available for devotion to alternate tasks. Thus consistent with Tiffany's (1990) model, smokers in withdrawal are predicted to demonstrate impaired performance on PM tasks that also require effortful (nonautomatic) processing. Because craving is hypothesized to occur independently from withdrawal states, a cue-reactivity measure was included to induce comparable levels of craving among smokers, permitting more careful examination of the effects of withdrawal. It should be noted that numerous existing theories explain the process of addiction and/or relapse, and that no one theory, including the two enumerated above, has yet to fully describe this complex and vast phenomenon (Brandon et al., 2007; West, 2001). Nonetheless, theories provide useful heuristics to guide hypotheses for research consideration.

An additional consideration for the poor response to treatment noted above may be that smokers capable of quitting on their own have done so as education about the health consequences of cigarette smoking have become more accessible to the general public. This leaves those who have been unsuccessful at quitting on their own seeking the aid of formal

treatment programs. Thus, members of this treatment refractory population are most likely to be seeking treatment for smoking cessation, and to contribute to the relapse rates in these programs.

Coping Skills

Models of Coping

Wills and Shiffman (1985) present a stress-coping model where substance use is conceptualized as a maladaptive coping skill. According to the stress-coping model, multiple coping responses are necessary during quit attempts, above and beyond the general need to cope with quit-related urges. During cessation attempts, an individual must exhibit coping responses for temptations/cravings to relapse, stressors that raise negative affect, withdrawal symptoms, and they must establish new sources of positive affect (other than substance use) (Wills & Shiffman, 1985).

Wills and Shiffman (1985) assert the view that substance use has become the predominant form of coping over time and with progressive use. Therefore, during cessation attempts, an individual's primary means of coping is being eliminated. Further complicating the process, the removal of the practiced coping skills (substance use) will occur simultaneously with an increase in stressors due to the addition of quit-related urges. This model underscores the importance of establishing new coping methods for individuals attempting cessation, as well as the difficulties encountered during such an attempt. Further, dependent substance users would be in need of general coping response training to replace substance use as a coping technique. Chaney, O'Leary, and Marlatt (1978) examined the impact of generalized (as opposed to drug-specific) skills training targeting appropriate responses in problematic situations on relapse at 1-year posttreatment. The authors found the skills training condition had significantly fewer days drunk, fewer total number of drinks, and

shorter relapse/lapse duration; suggesting that generalized problem-solving and coping skills may be important in replacing substance use as a primary means of coping. Others have noted that even the perception of poor coping skills is related to substance use disorders and that level of physiological reactivity may play a role in resorting to the use of substances for coping (Bobadilla & Taylor, 2007). Thus, coping responses targeting general stress management and/or emotional regulation to reduce physiological reactivity may be as important as coping targeting cessation/abstinence issues.

Shadel, Niaura, Goldstein, and Abrams (2001) compared high and low dependence smokers in a reaction time-based task (involving nonsmoking/coping and nonsmoking/neutral words) assessing processing of coping information under two conditions. In a within-subjects design, following the presentation of a smoking cue, smokers underwent the task once when given instructions to use cognitive avoidance coping and then again while given no coping instructions. Wills and Shiffman's (1985) coping model would predict that individuals with high dependence would have fewer coping information available to them (because they have come to rely on smoking as a coping resource and have gradually lost access to other coping resources). Thus, high dependence smokers would be expected to process coping information more slowly (Shadel, Niaura, Goldstein, & Abrams, 2001). However, the results indicated the opposite pattern, such that low dependence smokers demonstrated slower reaction times when given instructions to execute the cognitive avoidance coping skill. The authors reasoned that low dependence smokers may have more competing coping skills that would interfere and slow processing, resulting in slower reaction time (Shadel, Niaura, Goldstein, & Abrams, 2001). High dependence smokers demonstrated faster reaction times (an index of better cognitive processing) because they had no coping information to compete with the coping instructions provided during task.

11

Coping Skills Utilization

Use of coping skills is a predictor of successful abstinence (Haaga, 1989; Litt, Kadden, Cooney, & Kabela, 2003; Moser & Annis, 1996; O'Connell, Hosein, Schwartz, & Leibowitz, 2007; Shiffman, 1982, 1984); however, the most effective method of increasing utilization is not clear. Comparisons between CBT-based and other therapeutic approaches have failed to yield consistent differences in coping skills use (Litt et al., 2003; Morganstern & Longabaugh, 2000; Thorndike, Freidman-Wheeler, & Haaga, 2006). Litt et al. (2003) found equivalent increases in coping skills use regardless of treatment condition (CBT-based coping skills training vs. interactional therapy). The results of the Litt et al. (2003) study echoed the findings of a review paper examining the hypothesized mechanism of action for CBT in the treatment of alcohol dependence. Morganstern and Longabaugh (2000) were unable to support the hypothesis that CBT's effectiveness is achieved via coping skills utilization.

Findings that CBT-based approaches (which focus on skills deficits and instruction) do not produce greater coping skills use than comparison conditions are puzzling. As others have noted, it may be that simply engaging in behavior change or entering treatment provides the momentum for individuals to find their own individual methods of coping (Litt et al., 2003). Another possibility raised has been that coping skills instruction may only be useful (and therefore show a treatment effect) if the individual enters treatment with deficits, and there is some evidence that this treatment matching approach has validity. Kadden, Litt, Cooney, and Busher (1992) randomly assigned participants to interactional therapy or coping skills training treatment conditions. Results for each condition appeared to be related to level of pretreatment role-playing skill level, where individuals with poor role-play performance had better outcomes with the skills training approach and individuals who demonstrated fair

levels of performance with role-playing were best suited to interactional therapy. Another study found CBT and interactional approaches equivalent for lower levels of psychopathology, but CBT resulted in better drinking outcomes among individuals with higher levels of psychopathology (Kadden, Cooney, Getter, & Litt, 1989). This pattern was maintained in the 2-year follow-up analyses as well (Cooney, Kadden, Litt, & Getter, 1991). Together, these studies lend support to the idea that coping may be particularly helpful for those in need of skills instruction, but do not provide a full explanation for the inconsistencies noted above.

Due to the considerable ambiguity in attributing coping skills improvements to CBT-based treatments, several concerns have been raised about the ability to measure outcomes and evaluate hypotheses related to CBT-based treatments and coping skills (Morganstern & Longabaugh, 2000), including measurement, protocol adherence, study design, and population selection. Measurement of coping skills is difficult to assess, and current methods are not ideal. Evidence suggests retrospective recall of coping response execution has poor overlap with momentary assessment procedures (Stone et al., 1998), and self-report may only provide access to knowledge, not behavior. Behavioral role-playing assessment provides information about knowledge and execution skill, but does not necessarily reflect everyday use of these skills (Hawkins, Catalano, Gillmore, & Wells, 1989). Examination of the number of coping skills employed provides information about performance, but does not permit judgments regarding the adequacy or skillfulness of coping. Shiffman (1984) found an increase in the utilization of behavioral coping responses with treatment; however, treatment did not guarantee effectiveness of the coping response, indicating that the competence of the response may be an important consideration for measurement issues. However, Ball et al. (2007) noted that despite increases in both the number of and competence of coping response

for individuals receiving brief coping skills training compared to brief motivational enhancement, there were no differences in drinking outcomes between the two groups. So, competency of skill execution may not be ideal either. It should be noted, however, that the population targeted was non-dependent heavy drinkers, and population parameters may affect treatment response. Similarly, and despite finding differences in coping responses between the skills and control groups, Hawkins et al. (1989) were unable to tie the changes in coping responses to changes in drug use (with the exception of amphetamines and marijuana). The results of the Ball et al. (2007) and Hawkins et al. (1989) studies raise doubts about the necessity and effectiveness of coping skills in the treatment of substance use disorders. Further complicating measurement issues, cognitive coping may be particularly difficult to assess (Haaga, 1989).

The above concerns have spurned investigations of specific types of coping skills (i.e., active versus passive, behavioral versus cognitive), and possible differential effectiveness. Interestingly, there appears to be little difference in the type of skill employed. With the possible exceptions of a select few (self-punitive statements, willpower, and exercise are all regarded as less effective), individual copings skills show equivalent effects (O'Connell et al., 2007; Shiffman, 1984). Avoidance responses are typically regarded as less effective (Chung, Langenbucher, Labouvie, Pandina, & Moos, 2001), but the effectiveness of avoidance responses may be dependent on an individual's level of self-efficacy (Levin, Ilgen, & Moos, 2007). Rather than the type of coping response, the importance appears to lie in the number of skills employed (Moser & Annis, 1996; O'Connell et al., 2007). However, others have noted that the sheer quantity is not key, but rather the diversity. Specifically, using cognitive and behavioral techniques in combination (Shiffman, 1984), or having the ability to execute multiple responses may be necessary for success (Moser & Annis, 1996).

Despite concerns about the role of coping skills in the CBT model, coping skills do appear to be important for successful abstinence. Perhaps the most convincing evidence is found among individuals who do not execute a coping response, where the probability of remaining abstinent was 8% (Moser & Annis, 1996). The probability of remaining abstinent rises to 40% for individuals exhibiting one coping response and up to 80% for those using two responses (Moser & Annis, 1996). Similarly, Shiffman (1984) found 90%, 55%, and 13% relapse among individuals who executed no coping response, either a cognitive or behavioral strategy, or both a cognitive and behavioral strategy, respectively. In their study of relapsers, Brandon and colleagues (1990) noted that the majority did not report executing a coping response, and of those coping responses that were reported, the authors noted that the responses were 'primitive'.

Outside of the treatment outcome literature, differences between alcohol abusers and social drinkers have been noted in behavioral examinations of coping response skillfulness to alcohol-specific situations, despite equivalence of the two groups on behavioral ratings in general situations (Abrams et al., 1991). A similar pattern was identified among current smokers and quitters for smoking-specific intrapersonal situations, where quitters exhibited more skillful responses (Abrams et al., 1987).

Overall, the literature suggests coping skills are important for successful abstinence, although the several parameters surrounding coping skills have yet to thoroughly investigated. Questions remain regarding appropriate methods for effectively measuring skill performance, whether dedicating skills training is necessary, whether certain populations may be more in need of skills training than others, and why coping skills failures occur. Similar to the underlying objective of this paper (i.e., investigating memory failures as a possible

explanation for lack of coping skills utilization), other authors have noted the potential contribution of memory education/training to coping skills programs (Ball et al., 2007).

Effects of Nicotine Withdrawal on Cognitive Processes

Although Tiffany's (1990) model asserts that engagement of nonautomatic processes via craving is sufficient to cause limitations on cognitive resources, the literature reviewed in the following section indicates that nicotine withdrawal also has a negative impact on cognitive processing. Nicotine withdrawal encompasses a host of cognitive, physiological, and emotional symptoms, typically peaking in 1-3 days and persisting from 1-4 weeks (Hughes, 2007b). Current diagnostic criteria for nicotine withdrawal include negative affect (anxiety, irritability, anger, frustration, and dysphoria/depressed mood), difficulty concentrating, increased appetite or weight, restlessness, decreased heart rate, and insomnia (APA, 2000). A recent review of studies examining nicotine withdrawal concurred with these symptoms, with the exception of more specific wording for the insomnia criteria (Hughes, 2007b). Contrary to common perceptions regarding the severity of nicotine withdrawal, the syndrome causes clinically significant distress/impairment (Hughes, 2007a). It has been suggested that relapse may represent the most notable evidence of distress/impairment, as the majority of relapses occur during the peak of the withdrawal syndrome (Hughes, 2007a). Of the symptoms noted above, depression appears to be the most reliable predictor of relapse (Hughes, 1992; Hughes, 2007a).

Interestingly, withdrawal appears to be subject to expectancies, which exert the largest influence during the first week of cessation and are related to lapses (Gottlieb, Killen, Marlatt, & Taylor, 1987; McCarthy, Piasecki, Fiore, & Baker, 2006). Indeed, some smokers show elevations in withdrawal symptoms before quitting (McCarthy et al., 2006), emphasizing the role of anticipation and expectancy in quit attempts. As noted previously, roughly 2/3rds of

smokers want to quit, but less than half actually make an attempt to change their smoking behavior (CDC, 2002). It is possible that expectancy-driven pre-quit withdrawal symptom increases contribute to limiting the number of individuals who follow through with their intention.

There is considerable variability in withdrawal symptoms even within-subject (Hughes, Hatsukami, Pickens, & Svyikis, 1984; McCarthy et al., 2006), which may be partially due to expectancies. The influence of expectancies may play a role in gender effects noted among deprived smokers. Although females report greater distress from subjective symptoms of withdrawal, males appear to show greater impairment on objective tasks (Jacobsen et al., 2005). However, gender effects in withdrawal symptomatology are not always found (Robinson et al., 2007).

Unfortunately, many smokers attempting cessation will smoke in order to relieve withdrawal symptoms. However, evidence suggests that this process prolongs and/or intensifies withdrawal. Compared to abstinent smokers, individuals asked to reduce smoking levels reported greater desire to smoke and slower rate of decrease in cravings (Shiffman & Jarvik, 1976).

From the perspective of a substance user, the withdrawal effects experienced post-cessation can be viewed as negative punishment (Stolerman, 1991). Decreased concentration, attention, and other cognitive processes (as well as physiological symptoms) would motivate an individual's return to use for alleviation of noted deficits. Drug administration is then associated with a reinstatement of prior levels of functioning. Notably, regardless of whether nicotine use creates superior levels of functioning (e.g., attention) or whether functioning is at the level of a nonsmoker (as is the case with some cognitive processes for heavy smokers), the experience of decreased functioning as a product of withdrawal is followed by an

improvement in functioning with resumed drug use. Relapse is then rewarded (reinforced), both negatively (i.e., removal of withdrawal symptoms) and positively (i.e., pleasant effects of drug, reinstatement of prior levels of functioning) reinforced. There is initial evidence that memory tasks involving strategic processing (but not automatic processing) are enhanced by nicotine delivery (Rusted, Graupner, O'Connell, & Nicholls, 1994; Rusted, Graupner, Tennant, & Warburton, 1998; Rusted, Trawley, Heath, Kettle, & Walker, 2005; Warburton, Skinner, & Martin, 2001), and thus may be subject to this punishment/reinforcement hypothesis during cessation/relapse. The same can be said of nicotine-enhanced attention (Rusted, Caulfield, King, & Goode, 2000).

Consistent with this view, Zinser, Baker, Sherman, and Cannon (1992) found that smoking was rated as more pleasurable and enjoyable following 24 hours of deprivation compared to nondeprived smokers. The length of abstinence appears to be related to the reinforcing value of smoking with the value of smoking decreased as a function of the length of abstinence (Lussier, Higgins, & Badger, 2005). Importantly, Lussier et al.'s (2005) study provided an empirical basis for explaining the high rates of relapse in the first week of abstinence. While 14-day abstinence was associated with a decrease in the value of smoking, the 1-day and 7-day groups were equivalent. The authors suggest that the relationship between the reinforcing value of smoking and length of abstinence have a threshold rather than a linear relationship, and that it is possible that factors such as the withdrawal period have a role in determining this threshold point (Lussier et al., 2005).

Withdrawal effects have been noted in both attention and memory processes, and these deficits have been suggested as possible contributors to the relapse process (e.g., Mendrick et al., 2006). Sustained attention deficits as indexed by omission errors (and to a lesser degree accuracy) have been noted in deprived rats, peaking at 16 hours and returning to baseline

18

levels by 106 hours post-drug removal (Shoaib & Bizarro, 2005). Withdrawal effects on

sustained attention have also been noted in humans (Hirshman, Rhodes, Zinser, & Merritt,

2004). In a within-subjects design, Zack and colleagues (2001) found impairments in

inhibitory information processing following a deprived compared to nondeprived period

where participants demonstrated slower reaction times to smoking-related cues as opposed to

neutral cues. The authors suggest that smoking following a period of abstinence may be

reinforcing due to an ability to disregard smoking-related stimuli, leaving more processing

capacity available for other activities (Zack, Belsito, Scher, Eissenberg, & Corrigal, 2001).

Some have argued that the nicotine-induced improvements seen in other tasks (i.e., memory)

are better explained by generalized improvements in performance via reduced attentional

demand (Rusted & Warburton, 1992; Warburton et al., 2001). However, at least some aspects

of memory (e.g., associative learning, working memory) are affected directly by nicotine

administration (Blake & Smith, 1997; Warburton, Rusted, & Fowler, 1992). Pineda, Herrera,

Kang, & Sandler (1998) note that these inconsistencies may best be resolved by concluding

that nicotine contributes to more efficient information processing, and this effect may be seen

through both attention and memory.

Waters, Shiffman, Sayette, and colleagues (2003) demonstrated that the severity of

attentional bias was predictive of lapses; however, this predictive relationship failed to be

replicated in a later study (Waters, Shiffman, Bradley, & Mogg, 2003). Also notable, it is not

only deprived smokers, but also nondeprived smokers that demonstrate attentional bias

(Waters, Shiffman, Bradley, et al., 2003). One might question whether exsmokers may return

to nonsmoking levels of attentional bias, or remain at levels similar to current smokers.

Ehrman and colleagues (2002) found significant differences between nondeprived smokers

and nonsmokers. Exsmokers' level of attentional bias fell in between the smoker and

nonsmokers group, but was not significantly different from either group (Ehrman et al., 2002). Although not assessed in the study, the authors suggest future studies examine the length of abstinence in relation to change in exsmokers' level of attentional bias (Erhman et al., 2002). If exsmokers' responses continue to trend toward nonsmoking levels of bias, it would support findings regarding the loss in reinforcing value of cigarettes in relation to time (Lussier et al., 2005).

In addition to detriments in attentional processes, impairments in various aspects of memory have been identified. Verbal (Jacobsen et al., 2005), working (Blake & Smith, 1997; Heishman et al., 2006; Jacobsen et al., 2005; Mendrik et al., 2006), and episodic (Hirshman et al., 2004) memory components appear to be sensitive to effects of nicotine withdrawal. Other studies, however, have failed to identify withdrawal-related impairments to memory: working memory (Pineda et al., 1998), and short-term memory (Hirshman et al., 2004). Blake and Smith (1997) identified specific effects of nicotine withdrawal on central executive and/or articulatory loop processing in working memory, that were not present during articulatory suppression conditions. In addition, the authors did not find an effect of time, suggesting that the changes in performance were a function of memory rather than attention (Blake & Smith, 1997).

Deprived smokers show deficits in working memory compared to nondeprived smokers and nonsmokers (Mendrick et al., 2006). The observed deficits persisted in the second trial even though participants were permitted to smoke one cigarette. Interestingly, despite the continued impairment on memory-related measures, the participants reported reduced craving and withdrawal on subjective measures (Mendrick et al., 2006). As the authors note, this would suggest independent contributions of craving and withdrawal to memory impairments.

Prospective Memory

As stated above, PM is the process of remembering an intention to be carried out in the future. Sellen, Louie, Harris, and Wilkins (1997) describe PM further by distinguishing three components involved in these tasks. A successful PM task involves "(1) remembering *what* to do; (2) remembering the critical conditions under which it is to be done; and (3) recognizing the retrieval cues as such when they occur (p. 504; italics in text)." Thus, failure in a PM task may involve any one of these components, where an individual may forget that he was asked to pick up milk, he may forget that he was to do this activity on the way home from work, or he may fail to recognize the grocery store as a cue. In a similar vein, smokers wanting to quit may forget a coping skill, fail to identify the high risk situations to which the coping skill applies, or fail to utilize internal or external smoking cues as signals to execute the coping response.

PM can be distinguished from another form of memory, retrospective memory (RM), which refers to memories of past events. While PM is a distinct form of memory, the process of remembering an intention and carrying out the intention does require both RM and PM. Einstein and McDaniel (1996) explain the interaction of these two types of memory as a distinction between the process and the factual information necessary for this process to take place. PM is the memory of an intention, whereas RM is the memory of the content of the intention itself. Both are necessary for the intention to be carried out, yet they are separate components of memory. Studies on event-related brain potentials indicate the involvement of neural processes may overlap for retrieval procedures in both PM and RM, but that an additional neural process is utilized in PM and is not found for RM (West & Krompinger, 2004).

Two additional features serve to differentiate PM from other forms of memory: 1) the content of the memory is a plan rather than a past event or learning experience, and 2) self-cuing plays a more important role for PM (Sellen et al., 1997). This reliance on self-initiated retrieval of the PM plan may one of the more salient differences between PM and RM (Einstein & McDaniel, 2005). For RM, retrieval is often prompted by the environment (e.g., "Were there any messages for me while I was gone?", "Tell me about your last attempt to quit smoking"). For PM, we often do not have the luxury of such prompts ("Did you take your medication today?"). Instead, we rely on cues to aid in prompting retrieval of the PM plan (e.g., leaving the medication bottle on the counter). While helpful, cues are not always foolproof. One reason why we may fail to recognize cues may be due to the necessity of switching from regarding a stimulus as information to regarding a stimulus as a cue (Einstein & McDaniel, 2005; see also Graf & Uttl, 2001). For example, delivering a message to a friend will require that one recognize the person not only as a friend, but also as a cue for retrieval. In the case of a smoker, they may recognize a high-risk situation, but fail to bridge this to recognition of the situation as a cue for implementing the PM plan (i.e., use of a coping skill).

Graf and Uttl (2001) note further differences in PM and RM in laboratory-based tasks. A key distinction is the lack of instruction sets and reminders in PM tasks compared to RM tasks. The authors also suggest that PM is composed of subcomponents in much the same way as RM (e.g., short-term, long-term) and, as we gain knowledge about these subcomponents, the differences between PM and RM will be elucidated.

PM can consist of either time-based or event-based tasks (Einstein & McDaniel, 1990; Sellen et al., 1997; Smith & Bayen, 2004). The distinction is made by consideration of the context of intention execution. In a time-based event, the task would be completed when a certain time interval passes (e.g., checking blood sugar levels every four hours), or at a

specific time of day (e.g., taking a medication at 3pm). In contrast, event-based tasks are more likely to have salient external cues available to facilitate retrieval of the intention (e.g., return books to the library). Thus, the cues for these types of task differ, with event-based tasks often being contingent on external stimuli or situation (such as passing the library or seeing the books in the back seat of the car; Guynn, 2003) and time-based events requiring more internal monitoring (Sellen et al., 1997). Among smokers, event-based tasks may correspond to situations in which there are clear high-risk smoking stimuli present such as seeing others smoking, seeing a cigarette/lighter, going to a bar, drinking alcohol or sitting in a 'smoking chair'. Time-based events could be similar to the internal smoking cues experienced by smokers such as stress, anger, or negative affect. These high-risk situations would hopefully trigger the intention to execute a coping response.

Sellen et al. (1997) compared the pattern of thoughts related to both time- and event-based PM tasks in an *in situ* study. Participants wore electronic buttons to be pressed when completing a task and when having thoughts about the tasks. Fewer thoughts were reported for the event-based tasks than the time-based tasks, and time-based tasks were reported as more difficult by the participants. The authors suggest that in event-based tasks, participants reduce efforts to recall the intention (have fewer thoughts about task), and instead rely on contextual cues to remind oneself of an intention. These results would suggest that event-based tasks are less resource demanding that time-based tasks because it is possible to rely on the environment to prompt retrieval. Despite the differences noted in the Sellen et al. (1997) study, the level of interference (measured by slowed response latencies) appears to be independent of task type (Hicks, Marsh, & Cook, 2005). Rather, the specificity level of the intention determines the degree of task interference (Hicks et al., 2005).

Models of Prospective Memory

In real-world PM tasks, an individual is typically engaged in more than one ongoing task (McDaniel & Einstein, 2000). That is, the individual has more on his or her mind than remembering to complete a task later. Rather, the individual may be actively engaged in some other task (i.e., finishing paperwork) and must maintain the intention for following through at a later time. McDaniel and Einstein (2000) present the multi-process model of PM, outlining the processes by which a person maintains and recall intentions for future use while engaging in other activities. As noted by the authors, the model is based on event-based tasks, although it may apply to time-based tasks as well.

In an attempt to make sense of discrepant findings in the literature regarding the underlying mechanisms involved in PM, McDaniel and Einstein (2000) suggest multiple processes are engaged in the completion of a PM task, and that both automatic and nonautomatic processes are possible. An example of capacity-consuming monitoring efforts would be allocating ongoing attention toward remembering the task, or scanning periodically for event-related cues. Automatic processes would be less apparent to the individual. The multi-process model specifies several types of automatic processes that may be involved, including attention and memory-based systems (McDaniel & Einstein, 2000). Attentional processes can be automatic through reflexive attentive focus on relevant (or novel) stimuli, which prompts retrieval of the intention and requires little cognitive demand (McDaniel & Einstein, 2000). The automatic memory-based processes involve activations of the reflexive-association process (McDaniel & Einstein, 2005). According to their model, information regarding an intention is encoded with a cue. If the cue-intention association is strong and the cue presents, the PM intention will be spontaneously retrieved even if the intention was not on the person's mind (Einstein & McDaniel, 2005).

24

Overall, the importance of automaticity lies in the degree of cognitive capacity demands required by the process. If the process is spontaneous or reflexive, less cognitive capacity will be used than in comparison to a task that demands the devotion of cognitive resources. While the authors hold that the spontaneous processes are most common, the model suggests that multiple processes are possible in PM (Einstein & McDaniel, 2005). The process that is predominately responsible for the PM task can change dependent on task characteristics, and more than one process may be involved in a given PM task (McDaniel, Guynn, Einstein, & Breneiser, 2004). Task characteristics that play a role in PM include the 1) importance of the task, 2) features of the cue (distinctiveness and association of cue with the intention), 3) features of the secondary task (focus of task, demands of task, degree of overlap between PM and secondary task, degree of engagement required by the secondary task), 4) degree and type of planning, and 5) individual differences (McDaniel & Einstein, 2000).

Guynn (2003) presents an elaboration of the multi-process theory by presenting a model for the controlled monitoring processes involved in event-based PM. The two-process model of strategic monitoring stipulates that a prospective retrieval mode is engaged (component 1) which employs cues as signals to retrieve the intention. These cues may be either internal states or external events/situations. The second component is the process, called checking, that brings the cue to the attention of the individual. Checking involves both scanning for a particular cue and evaluating whether the cue is appropriate for the intention (Guynn, 2003). Both of these would require cognitive capacity involvement. In the test of this model, Guynn (2003) demonstrated that reaction time varied according to the level of demand involved in the task. Reaction time was best in the control condition (when no PM task was given) where the participant neither needed to engage the retrieval mode nor check for cues, and worst when the participant was required to complete both of these processes (engage in

the PM task). Reaction time performance fell between these tasks when the participant was forced to engage the retrieval mode, but not the checking process (participant needed to remember the task for future trials, but did not expect a cue during the present trial).

As a third alternative, the preparatory attentional and memory processes (PAM) theory (Smith, 2003) differs from the multi-process theory by specifying that all PM tasks occur as effortful, capacity-consuming events. More specifically, tasks are not automatic and always come at a cost, although the level of demand on cognitive resources may vary given the task parameters. In contrast to McDaniel and Einstein's (2000) model which includes a low-cost spontaneous retrieval option, the Smith (2003) model suggests that preparatory processes are engaged continuously to monitor for retrieval cues until the PM task is executed. Smith and Bayen (2004) present a mathematical model based on the PAM theory that compared the fit of the model for an automatic versus preparatory processing. The final statistical model did not fit the spontaneous-retrieval processing as well as the preparatory processing model. It is noted by the authors that the event-based task used in the study may have been a situation where automatic processing is not required, thus the multi-process theory may still be applicable and further research is necessary to investigate what tasks or situations are more likely to involve automatic processing. Regardless, it is clear that at least some tasks are less likely to involve automatic processes.

Influences on Prospective Memory

Researchers have speculated that the variability in PM processes may be nature's way of ensuring that such a vital process for human functioning is always accessible (McDaniel & Einstein, 2000). Regardless of the reasons, it is clear that such variability exists. Research concerning PM has focused on the various conditions which affect PM performance and the impact of PM demands. Within the realm of clinical applications, the effects of mood states

on PM, PM performance in clinical populations, and the clinical treatment potential for PM

deficits has received attention.

Attention, Working Memory, and PM. As discussed above, a major question in the

PM literature is the presence of (and factors related to) automaticity in the PM process. The

multi-process model makes the argument that the level of automatic processing changes

dependent on task characteristics, one of the factors being whether monitoring is necessary or

reliance on external cues is sufficient (McDaniel & Einstein, 2000). One method for

evaluating the presence of automatic processing is to assess performance by varying the

attentional demand of the secondary tasks. This process assumes that cognitive resources are

limited. Thus, when the PM process is controlled rather than spontaneous, a trade-off occurs

as secondary task demands increase (see also Marsh, Hancock, & Hicks, 2002). However,

when the PM task is automatic, no detriments will be seen even with increasing the demand of

the secondary task.

An alternate way of conceptualizing the contribution of cognitive resources is in terms

of working memory involvement in the PM task. By systematically varying the demand of the

secondary task involving the working memory system, we can see that more failures occur in

both time- and event-based PM tasks as the demand of the working memory task increases

(Logie, Maylor, Della Sala, & Smith, 2004; Marsh et al., 2002). The failures in PM tasks may

indicate that working memory was involved in keeping the intention current and accessible

for this relatively short laboratory task (Logie et al., 2004). Thus, the task involved controlled

monitoring, and fewer resources were available for devotion to the working memory task.

Marsh and Hicks (1998) investigated the involvement of working memory in PM tasks

by varying the component involved. Using a task that emphasized the phonological loop, the

visuospatial sketchpad, or the central executive, the design allowed assessment of

susceptibility to task demand in each of these domains of working memory on PM performance. PM performance was affected by increasing the demand in the central executive condition only. This effect was not found for either the phonological loop or visuospatial sketchpad. In a follow-up of Marsh and Hicks' (1998) experiment, the results were not replicated (van den Berg, Aarts, Midden, & Verplanken, 2004). The authors hypothesize that the difference in results may be attributed to whether monitoring is required (or utilized) by the participant. That is, when monitoring is utilized, the PM task will be negatively affected as the demand of the central executive task increases. When monitoring is not necessary, these effects will not be present.

Mood and Anxiety Influences on PM. Depression and anxiety have been examined as factors that may affect PM performance. In a sample of undergraduates, Harris and Menzies (1999) found that anxiety, but not depression, was negatively correlated with event-based PM task performance. It is possible that a curvilinear function best captures the relationship between anxiety and the number of errors performed on a PM task as was found in a sample of older adults (Cockburn & Smith, 1994).

In contrast to the Harris and Menzies (1999) findings, another study utilizing a time-based PM task did find significant differences between clinically depressed and nondepressed participants (Rude, Hertel, Jarrold, Covish, & Hedlund, 1999). The design of the task required more effortful monitoring and may suggest differential effects of negative affect on PM task types and level of automatic/nonautomatic processing (Rude et al., 1999).

Kliegel and colleagues (2005) investigated the effects of negative mood induction on time-based PM performance. Individuals in the negative mood condition showed greater impairment in PM performance than the control condition, and these errors were attributed to decreased timeliness in responding (as opposed to forgetting the response; Kliegel et al.,

2005). The nature of the mood induction permitted examination of the effects of mood on PM performance in a nonclinical sample, and suggests that emotional valence is relevant to PM performance even in the absence of psychopathology.

Negative affect and lack of positive affect are often reported by smokers following cessation. Indeed, negative affect is often regarded as the most important and reliable predictor of relapse (Hughes, 1992, 2007a). Due to the possible influence on PM performance, the current study included a measure of positive and negative affect.

PM Training in Special Populations

Impaired PM performance has been identified in the elderly (Einstein, McDaniel, Smith, & Shaw, 1998; Huppert, Johnson, & Nickson, 2000; Martin & Schumann-Hengsteler, 2001; McDermott & Knight, 2004), among samples of individuals with dementia (Huppert et al., 2000; Smith, Della Sala, Logie, & Maylor, 2000), stroke patients (Brooks, Rose, Potter, Jayawardena, & Morling, 2004), and individuals with traumatic brain injury (Kliegel, Eschen, & Thone-Otto, 2004; McCauley & Levin, 2004; Shum, Valentine, & Cutmore, 1999). The real-world implications of PM impairment for these populations are widespread. Daily functioning, social/occupational relationships, and medication compliance would be at risk due to poor execution of intentions. Vedhara et al. (2004) investigated the translation of computerized assessment of PM performance to complex real-life issues, focusing on medication compliance among elderly diabetes patients. Their assessment of medication adherence indicated that medication compliance was present on only 62% of days, and patients were far more likely to make omission errors rather than repetition errors (35.4% days when doses were omitted versus 2.5% days when repetition error occurred). Given the mediocre levels of medication compliance, one interpretation may be that a PM failure is occurring, but a question of interest for the study investigators was whether this real-life

occurrence would concur and be detectable using computerized assessments of PM performance. The results indicated that overall PM performance on computerized tasks was associated with the number of days correctly taking medication and number of days committing omission errors, but not the number of days with repetition errors (Vedhara et al., 2004). The ecological validity of computerized laboratory assessments of PM may be low, but as the results of the Vedhara et al. (2004) study suggest, may still access the same processes and provide a reasonable approximation of real-world behavior.

One rather interesting application of noted PM deficits is that of disease detection. Caregivers appear to be particularly sensitive to PM failures in Alzheimer's patients, possibly suggesting the utility of monitoring the caregiver-reported progression of errors in their patients as a screening tool (Smith et al., 2000).

As PM deficits have been discovered in clinical populations, researchers have turned toward interventions to improve functioning. Fortunately, current technological advances have provided the means to assist patients with PM deficits. The primary intervention is to provide visual or audible cues through electronic equipment to prompt memory of intentions (Jung Kim, Burke, Dowds, Boone, & Parks, 2000; Oriani et al., 2003; Van Den Broek, Downes, Johnson, Dayus, & Hilton, 2000; Yasuda et al., 2002). Voice prompts have been used successfully to reduce PM failures with the use of IC Recorders and Electronic Memory (Oriani et al., 2003; Van Den Broek et al., 2000; Yasuda et al., 2002). Voice cues typically have recorded messages to prompt behavior and are programmed to be delivered at appropriate times. These electronic aids provide an advantage over general pager alerts by providing a specific prompt (overcoming any failures to remember what a page alert was meant to signify; Kapur, Glisky, & Wilson, 2004). Palmtop computers can provide both auditory and visual cues, and are perceived as useful by patients with brain injury (Jung Kim

et al., 2000). The feasibility of using somewhat sophisticated electronic devices may be affected by the individual's ability to learn and severity of memory deficits (Thone-Otto & Walther, 2003), and extensive training may be necessary (Kapur et al., 2004). Either alternative or adjunctive to external memory aids, training programs involving education and memory strategies have shown the ability to improve performance (Schmidt, Berg, & Deelman, 2001; Villa & Abeles, 2000).

In a closely related area of research, implementation intentions may be an additional method of improvement of PM impairment. Implementation intentions involve the rehearsal of an explicit and detailed plan for executing a targeted behavior, resulting in an increase of situational cues that should prompt retrieval of the cue at the necessary time (Gollwitzer, 1999). Use of implementation intentions has increased PM performance in laboratory-based tasks, but the benefits may be limited to PM tasks which have no explicit external cues for retrieval and are more reliant on self-monitoring (Chasteen, Park, & Schwarz, 2001). This same procedure has been applied to real-world PM behavior (medical regimen compliance) with success (Liu & Park, 2004). The authors hypothesize implementation intentions capitalize on the lack of age-related declines in automated cognitive processes to improve behavior (Liu & Park, 2004).

Practical applications of implementation intentions to behavior change have shown promising effects across a wide variety of behavioral domains. A recent meta-analysis using 94 experiments found that formulation of plans resulted in medium-to-large size positive effect on goal attainment ($d = 0.65$; Gollwitzer & Sheeran, *in press*). Armitage (2004) investigated the impact of formulating a plan for reduction of dietary fat intake compared to a control group which was asked to reduce dietary fat intake without formulating a specific plan of action. The control and experimental groups were equivalent in motivation. A significant

reduction in fat intake was found for the experimental group, suggesting a very minimal intervention may have an impact on behavior change (Armitage, 2004). Implementation intentions have also been applied to smokers and utilization of coping skills. College smokers identified high-risk situations in which they typically smoke, and were asked to form plans for executing a specific coping response (selected from a provided list) in a specific high-risk situation (Greene, 2004). Compared to smokers who were provided with list of coping responses but did not formulate implementation intentions, the experimental group smoked less frequently (Greene, 2004). Although this was not a treatment-seeking sample of smokers, the results suggest a promising avenue for further study and provide a benefit to current treatment programs.

If PM deficits are identified in smokers, it is reasonable to assume from the results of these studies that the deficits could be improved upon through incorporation of brief memory-related content into existing smoking cessation interventions. With the growth and greater accessibility of electronic devices, this may represent an additional method of intervention for smokers wanting to quit.

PM and Drug Use

While there are few studies investigating PM in the area of substance use, those that have been published demonstrate remarkable similar findings across studies and substances. However, it should be noted that with few exceptions, the experiments were conducted by the same research group and used the same measure of self-reported PM performance. This is not to say that the results are invalid, merely that the findings could be considered a product of methodological consistency. Arguments against this would be the use of two data collection methods (internet and in laboratory collection) and the fairly rigorous use of covariates to equate the comparison groups as much as possible statistically.

Alcohol Use. Heavy alcohol use has been examined as a contributor to impairments in PM performance. Heavy college drinkers who exceed the minimum criteria for heavy use (21 drinks per week for females, 28 drinks per week for males) but had not been diagnosed with alcohol dependence completed a self-report questionnaire assessing PM performance (Heffernan, Moss, & Ling, 2002). Compared to a light drinking/non-drinking control group, heavy drinkers reported significantly greater levels of impairment in all three aspects of PM measured (Heffernan et al., 2002). No differences were found among the groups for the number of coping strategies employed (Heffernan et al., 2002). The same finding of global impairments in PM performance among heavy drinkers was replicated in a web-based study using a larger sample (N = 763; Ling, Heffernan, & Buchanan, 2003). These effects do not appear to be the result of long-term alcohol use, and have been identified in adolescents reporting excessive alcohol consumption after controlling for other drug use (Heffernan & Bartholomew, 2006).

A recent study investigated the possible relationship between self-reported central executive processing performance and PM impairment among heavy drinkers (Heffernan, Ling, & Bartholomew, 2004). Heavy alcohol consumption was associated with impairments in all three domains of PM assessed, as well as central executive errors (Heffernan, Ling, & Bartholomew, 2004).

MDMA Use. In an attempt to access a larger sample of MDMA and cannabis users, Rogers et al. (2001) designed a web-based study to assess cognitive difficulties. Self-reported PM performance and common problems with everyday memory were assessed. The analyses indicated that cannabis and MDMA are related to unique aspects of memory problems. Short-term PM, internally cued PM, and everyday memory difficulties were associated with the

level of reported cannabis use, whereas long-term PM was related to the level of MDMA use (Rogers et al., 2001).

Global PM performance appears to be impaired in MDMA users according to self-reported memory functioning (Heffernan, Jarvis, Rodgers, Scholey, & Ling, 2001; Heffernan, Ling, & Scholey, 2001). Heffernan, Jarvis et al. (2001) found deficits in short-term, internally-cued, and long-term habitual PM functioning (Exp. 1). A second experiment by the authors replicated the same deficits with the exception of internally-cued PM (Exp. 2; Heffernan, Jarvis, et al., 2001). The variability is more consistent with the findings from the Rogers et al. (2001) study where types of PM functioning were uniquely associated with either cannabis or MDMA use. Heffernan, Ling, & Scholey (2001) suggest that level of MDMA use or concurrent cannabis use may contribute to these discrepant findings.

Additionally, central executive functioning measured by fluency tasks is impaired among MDMA users (Heffernan, Jarvis, et al., 2001). These findings suggest that either (1) PM and central executive processes are related (Exp. 2; Heffernan, Jarvis, et al., 2001), or alternately, that (2) the damage caused by drug behavior among MDMA users is diffuse enough to damage both systems of memory functioning. Further, it has been suggested that factors related to the use of MDMA (e.g., physical exertion, thermal body temperature, hydration) may exacerbate the negative effects (Parrott, 2004). In particular, thermal self-ratings and extent of dancing while using MDMA are associated with self-reported long-term PM problems (Parrott et al., 2006).

Using a different method of investigating the pattern of PM performance in MDMA users, Zakzanis, Young, and Campbell (2003) found impaired PM performance in MDMA users on two of the three PM tasks given compared to controls. Participants were asked to perform tasks (i.e., relay a message, ask a question in response to a signal) while involved in a

34

battery of assessment measures for intelligence and memory. The tasks used in the study more closely assessed PM performance as it might occur in everyday life, providing additional support for PM deficits in MDMA users beyond self-reported data.

Cigarette Smoking. Heffernan, Ling, Parrott, et al. (2004) assessed nonsmokers, light smokers (1-4 cigarettes per day), moderate smokers (5-14 cigarettes per day), and heavy smokers (15 or more cigarettes per day) for impairments in PM performance (using the PMQ) and for everyday memory performance. Due to psychometric concerns, only the long-term PM scale was used for analyses. Heavy smokers reported significantly greater impairment in long-term PM performance than either nonsmokers or light smokers (Heffernan, Ling, Parrott, et al., 2004). A linear trend for level of smoking rate was also reported (Heffernan, Ling, Parrott, et al., 2004).

Interestingly, acute administration of nicotine appears to improve PM performance in both regular smokers and nicotine-naïve participants when task demands were low (Rusted & Trawley, 2006). However, when concurrent task demands were more complex, individuals receiving nicotine (but not placebo) showed impairment in PM performance. The authors hypothesize that arousal and performance followed an inverted U-curve, such that moderate levels of arousal provided by nicotine result in improved performance. However, the arousal resulting from the combined nicotine plus a demanding task created an arousal overload. Clearly, additional studies are needed in this area before definite conclusions can be made, but the initial findings suggest PM performance is negatively correlated with smoking (at least under cognitively demanding conditions).

Statement of Purpose and Hypotheses

Coping skills have been identified as an important predictor of abstinence. Execution failures are largely unexplained and uninvestigated phenomena which have direct relevance to relapse in substance users. PM may be a mechanism by which these failures occur (Brandon et al., 2004), and have the potential to be worsened by craving and withdrawal states which are hypothesized to deplete available cognitive resources. In the current study, PM performance was examined in smokers with access to nicotine and smokers deprived of nicotine for 24 hours. As the literature on PM in smokers is sparse, nonsmokers were also included as a comparison group. The purposes of the paper are to 1) identify the pattern of performance across nonsmoker, deprived smoker, and nondeprived smoker groups; 2) assess possible additive effects of craving and withdrawal in smokers to detriments in reaction time and PM performance measures; 3) examine the assessment of PM via two modalities (laboratory task and self-report questionnaire); and 4) examine the relation of mood and level of reported nicotine withdrawal to PM measures. As potential high-risk situations can be external situations (i.e., seeing other smokers) and internal events (i.e., negative affect), time- and event-based PM performance were examined. Both PM tasks were constructed in an effort to engage effortful rather than automatic processing in order to increase chances of finding an effect, based on the theorized involvement of automatic and nonautomatic cognitive processes in PM and drug dependence. Craving has been identified as a cognitively demanding construct in a recent model of drug automaticity (Tiffany, 1990); however, given the impact of withdrawal on cognitive processing identified above, we hypothesize that craving and withdrawal will exert additive (negative) influences. Thus, both deprived and nondeprived smokers completed an *in vivo* cue reactivity task. This task was designed to increase craving to smoke. This would allow us to compare individuals experiencing high

36

craving during nonwithdrawal states to individuals experiencing both high craving and withdrawal symptoms.

Recently, a growing emphasis on the importance of cognitive variables has emerged in the addictions literature (Brandon et al., 2004; Ryan, 2002; Tiffany, 1990; Waters & Sutton, 2000; Waters & Leventhal, *in press*). Even beyond the addictions area, the potential benefits of approaching human behavior with consideration to both clinical and cognitive psychology have been noted (Gollwitzer & Sheeran, in press; Roskos-Ewoldsen, 2006). The current paper attempts to combine these areas by applying a largely cognitive construct, PM, in explaining the complex behavioral phenomenon of relapse. Significant effects may suggest a possible mechanism involved in the relapse process, a mechanism that is clinically relevant and may have the potential to be malleable. Although identification of the above hypothesized relationships would be an important first step, further research would be required to determine the relation of such an effect to current models of relapse.

The following hypotheses are presented:

1) Given the results of previous research on PM performance in substance users, nonsmokers are expected to demonstrate better performance (in accuracy and reaction time) than smokers.

2) According to Tiffany's (1990) cognitive processing model which posits cravings involve nonautomatic cognitive processing, smokers reporting high levels of craving would be expected to have slower reaction times and more impaired PM performance than smokers reporting low levels of craving.

3) Deprived smokers will demonstrate greater impairment (decreased accuracy, slower reaction times, and impaired PM performance) due to the decrease in available cognitive resources compared to smokers with access to nicotine.

While Tiffany's (1990) model discusses solely craving, others (Mendrick et al., 2006; Sayette & Hufford, 1994) have suggested possible additive demands on cognitive process by craving and withdrawal. Further, studies investigating the effects of nicotine withdrawal on memory and attention provide additional evidence to suggest greater impairments will be identified in the deprived condition.

4) Slower reaction times are expected for the intention-based trials compared to the baseline LDT task, indicating additional cognitive demand was necessary while maintaining an intention.

5) Negative affect will be positively associated with impairments in PM performance, reaction time, ratings of withdrawal, and reported urge to smoke.

6) Self-reported PM performance as measured by the PMQ will be positively correlated with performance on the two lab-based assessments of PM functioning.

7) PM performance (as measured by the PMQ and lab tasks) will be positively correlated with nicotine dependence, smoking rate, and number of years smoking.

Method

Participants

All participants were over the age of 18. Smokers and nonsmokers were targeted for recruitment among two populations: college students and community residents. The decision to target two populations was guided by evidence that college smokers exhibit considerable variability in their daily and weekly smoking habits (Colder et al., 2006). Thus, college smokers may average the same number of cigarettes per day (CPD) as community subjects, but the topography of their smoking patterns may differ. In the past, college-age smoking has been viewed as a behavior that many people mature out of, much as with alcohol use. Unfortunately, a larger percentage of nicotine users become dependent than is the case for other substances. This underscores the importance of addressing college-age smoking and cessation efforts. The inclusion of both community and college smokers in the present study would permit examination of the constructs of interest in each sample.

Community members were recruited through advertisements for a paid nonmedical research opportunity in two southern cities. Advertisements were placed in local newspapers and Internet message boards, and fliers were distributed in the community and on local campuses. Responders to the advertisements were screened over the phone for current smoking rate, age, and current dependence to drugs other than nicotine. Inclusion criteria for community smokers specified smoking at least 10 CPD for a minimum of 12 months. Nonsmokers were defined as having never smoked a cigarette (a maximum of two attempts was permitted) and never having used other methods of nicotine delivery. Individuals were screened and excluded for current substance dependence or past smoking. Qualified individuals were scheduled for an appointment. Smoking participants were randomly assigned a nicotine nondeprived or deprived (24-hours) condition.

The student sample was recruited via a psychology subject pool at a large southern university. Extra credit was provided for participation. Inclusion criteria for student smokers were more restrictive, specifying 15 CPD for at least one year. All other inclusion and exclusion criteria remained the same. Recruitment from both populations was difficult. In Table 1, the numbers of individuals involved from screening to completion are presented. A large percentage (46%) of screened individuals in the college sample did not qualify to participate due to having smoked in the past or currently smoking too few cigarettes daily. While relatively few qualified individuals declined to participate, the no show/cancellation rates were high for both the college and community sample. Non-participators ($M = 35.74$, $SD = 13.94$) were significantly older than participators ($M = 26.40$, $SD = 10.54$), $t(34.78) = 3.23$, $p = 0.003$, and more likely to be smokers, $\chi^2(1) = 22.18$, $p < 0.001$. No gender differences were present in rate of participation, $\chi^2(1) = 0.50$, $p = 0.48$. Among smokers, nonparticipators did not report higher daily rates of smoking, but had been smoking for more years compared to participators, $t(41) = 2.44$, $p = 0.019$.

The final sample sizes were ten smokers and 72 nonsmokers from the college sample, and 16 smokers and 22 nonsmokers from the community sample, comprising a total sample size of 120. Table 2 presents the demographic and descriptive information by smoking status for each of the targeted recruitment populations (college and community). Due to low overall recruitment numbers, the samples were not analyzed separately. Instead, the college and community samples were combined. Descriptive data for the combined sample by smoking status is presented in Table 3. The combined sample sizes by smoking status are 12 nondeprived smokers, 14 deprived smokers, and 94 nonsmokers. Due to difficulties obtaining sufficient samples of smokers, nonsmokers were over-recruited to provide sufficient power for analyses not dependent on smoking status (i.e., negative affect).

Table 1

Screening, Qualification, and Attendance Data for Smokers and Nonsmokers by Sample

Sample	Smokers	Nonsmokers	Total
College			
Screened	70	126	197
Qualified/Unqualified	16/54 (all <20CPD)	90/36	107/90
Declined	1	7	8
No Show/Cancelled	5	11	17
Completed	10	72	82
Community			
Calls received	--	--	114
Screened	62	38	99
Qualified/Unqualified	56/6	30/8	86/14
Declined	5	1	6
No Show/Cancelled	35	6	41
Completed	16	22	38

Notes. Smoking status on 1 no-show is unknown. CPD = cigarettes per day.

Measures

Smoking Status Questionnaire

The Smoking Status Questionnaire (SSQ; see Copeland, Brandon, & Quinn, 1995; see Appendix A) includes several demographic questions and a measure of nicotine dependence (Fagerstrom Test for Nicotine Dependence, FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991). The FTND is a modified version of the Fagerstrom Tolerance Questionnaire (FTQ; Fagerstrom, 1978), with improved internal consistency, greater face validity, and predictive ability (Radzius, Moolchan, Henningfield, Heishman, & Gallo, 2001; Payne, Smith, McCracken, McSherry, & Antony, 1994). Questions from the FTQ

41

Table 2

Demographic and Descriptive Information by Smoking Status and Sample

Sample	Nondeprived Smokers	Deprived Smokers	Nonsmokers	Total
College	($n = 4$)	($n = 6$)	($n = 72$)	($n = 82$)
Age	19.25 (0.96)	18.83 (1.33)	21.00 (2.05)	20.66 (2.07)
Sex (% Female)	16.7	25.0	79.2	72.0
Ethnicity (%)				
Caucasian	100.0	83.3	8.3	18.3
African American	0.0	16.7	6.9	7.3
CO (ppm)	14.00 (9.42)	8.33 (2.73)	1.67 (0.84)	2.83 (3.84)
Average Daily Cigarettes	19.5 (3.32)	18.75 (2.09)	--	19.05 (2.50)
Years Smoking Daily	3.88 (1.44)	2.92 (0.80)	--	3.30 (1.14)
FTND	5.50 (1.91)	3.83 (1.47)	--	4.50 (1.78)
Shipley Part 1 Raw Score	30.25 (3.50)	28.83 (2.64)	28.70 (3.24)	28.79 (3.20)
MAST Total	8.75 (4.92)	6.67 (4.13)	4.31 (2.75)	4.70 (3.14)
Dast Total	2.25 (2.06)	6.17 (3.54)	0.79 (1.01)	1.26 (1.96)
Community	($n = 8$)	($n = 8$)	($n = 22$)	($n = 38$)
Age	43.50 (8.39)	33.88 (12.47)	32.59 (12.30)	35.16 (12.16)
Sex (% Female)	12.5	12.5	63.6	42.1
Ethnicity (%)				
Caucasian	50.0	50.0	40.9	44.7
African American	50.0	50.0	27.3	36.8
CO (ppm)	21.75 (7.65)	6.00 (2.45)	1.10 (0.72)	6.80 (9.23)
Average Daily Cigarettes	20.13 (5.22)	16.44 (4.14)	--	18.28 (4.93)
Years Smoking Daily	24.50 (8.45)	11.64 (4.87)	--	18.50 (9.48)
FTND	5.00 (1.41)	4.50 (1.85)	--	4.75 (1.61)
Shipley Vocabulary Score	29.50 (5.26)	28.63 (10.01)	30.48 (3.84)	29.86 (5.80)
MAST Total	17.38 (13.76)	12.63 (12.57)	5.50 (9.37)	9.50 (11.86)
DAST Total	8.13 (8.82)	8.25 (8.61)	0.73 (1.28)	3.87 (6.61)

Notes. Means and standard deviations are presented unless otherwise specified. Sex information was unknown for 11% of the college sample. For the college sample, ethnicity was unknown for 69.5% of the sample, and for both samples, percentages may not add to 100% due to the 'Other' category not listed in table. ppm = parts per million, CO = carbon monoxide, FTND = Fagerstrom Test of Nicotine Dependence, MAST = Michigan Alcohol Screening Test, DAST = Drug Abuse Screening Test.

Table 3

Demographic and Descriptive Information for Total Sample by Smoking Status

Combined Sample Characteristics	Nondeprived Smokers (*n* = 12)	Deprived Smokers (*n* = 14)	Nonsmokers (*n* = 94)	Total (*n* = 120)
Age*	35.42 (13.69)	27.43 (12.00)	24.64 (8.85)	26.40 (10.54)
Sex (% Female) †*	16.7	14.3	75.5	62.5
Ethnicity (%) †*				
Caucasian	66.7	64.3	16.0	26.7
African American	33.3	35.7	11.7	16.7
CO (ppm)**	19.17 (8.72)	7.08 (2.75)	1.54 (0.85)	4.07 (6.29)
Average Daily Cigarettes	19.92 (4.52)	17.43 (3.51)	--	18.58 (4.12)
Years Smoking Daily**	17.63 (12.21)	7.62 (5.71)	--	12.42 (10.52)
FTND	5.17 (1.53)	4.21 (1.67)	--	4.65 (1.65)
Shipley Part 1 Raw Score	29.75 (4.59)	28.71 (7.53)	29.11 (3.45)	29.13 (4.20)
MAST**	14.5 (12.05)	10.07 (10.05)	4.59 (5.11)	6.24 (7.47)
DAST**	6.17 (7.69)	7.36 (6.78)	0.78 (1.07)	2.08 (4.20)
Withdrawal**	26.64 (13.99)	54.87 (27.70)	17.14 (14.56)	22.45 (20.34)
PANAS Positive	28.25 (6.27)	27.71 (5.47)	30.68 (7.26)	30.10 (7.03)
PANAS Negative**	15.25 (5.75)	20.00 (8.63)	13.04 (3.31)	14.07 (4.98)

Notes. †Data is missing for a considerable portion of ethnicity and sex data among the college sample. ppm = parts per million, CO = carbon monoxide, FTND = Fagerstrom Test of Nicotine Dependence, MAST = Michigan Alcohol Screening Test, DAST = Drug Abuse Screening Test, PANAS = Positive and Negative Affect Schedule. *Significantly different distributions of frequencies. **Significant difference in means between groups.

which were unable to distinguish between biochemical results from heavier and lighter

smokers were deleted from the FTND. Specifically, the question on inhalation patterns and

nicotine yield were not included. Coefficient alpha was reported at 0.61 for the FTND

(Heatherton et al., 1991).

Positive and Negative Affect Schedule

The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen,

1988; see Appendix B) includes two scales, providing a brief measure of positive and

negative affect. Each scale (positive and negative affect) consists of 10 items. Participants rate

the extent to which they experience each of the states listed on a five-point scale ranging from

slightly or not at all to very much. This measure was designed to be flexible in the choice of

time period the participant is asked to consider. The probability of having experienced a given

mood increased as the time periods lengthened (moment, today, past few days, past few

weeks, etc.) (Watson et al., 1988). Reliability coefficients are provided for each of the time

periods. For the current study, instructions were given to answer in the present, "right now,

that is, at the present moment" in order to assess the impact of current affect states on

performance. Coefficient alphas (moment time period) for the positive and negative affect

scales were .89 and .85, respectively. Test-retest reliability improved as time period

lengthens; however, the authors point out that even the moment time period demonstrated

stability (.54 for positive affect and .45 for negative affect). A principal components analysis

produced two factors (positive and negative affect), accounting for 62.8% of the variance in

the moment time period. Correlations with other commonly used measures were reported, but

the moment time period was not used in those analyses.

Measures of negative and positive affect were included in the present study in order to

better understand the relationship between direct effects of withdrawal on memory

performance and indirect effects of withdrawal through other changes (i.e., increased negative affect, decreased positive affect). As noted in the Blake and Smith (1997) study, it is possible that changes in affect are responsible for memory deficits and this relationship has not been fully assessed.

Minnesota Nicotine Withdrawal Scale

The original scale of the Minnesota Nicotine Withdrawal Scale (MNWS) assessed nicotine withdrawal symptomology as specified by the DSM-III (Hughes & Hatsukami, 1986). More recent modifications have adjusted the scale to fit DSM-IV criteria (craving was not included; Hughes & Hatsukami, 1998; see Appendix C). The scale used for the current study included the following items: anger/irritability/frustration, anxiety/nervousness, difficulty concentrating, impatience/restlessness, hunger, awakening at night, and depression. Participants responded to a 100mm visual analogue scale using anchors of 'not at all' and 'extreme'. Participant responses were calculated to give a mean score across symptoms as suggested by the authors (Hughes & Hatsukami, 1998). In a recent comparison, three popular withdrawal assessment instruments were determined to be relatively equivalent in terms of psychometric properties; however, the MNWS provides an advantage in having fewer items and requiring less time to complete (Etter & Hughes, 2006).

Prospective Memory Questionnaire

The Prospective Memory Questionnaire (PMQ; Hannon, Adams, Harrington, Fries-Dias, & Gibson, 1995; see Appendix D) consists of 52 questions and provides four subscale measures (short-term habitual PM, long-term episodic PM, internally-cued PM, and techniques to remember). The response scale for each item ranges from 1 to 9. For each PM subscale score, higher scores indicate more difficulty with PM. For the techniques to remember scale, a higher score is indicative of the use of more memory strategies. The PMQ

has good validity and reliability (Hannon et al., 1995), and has been used in several studies of self-reported PM performance among substance users (Heffernan & Bartholomew, 2006; Heffernan, Jarvis, et al., 2001; Heffernan, Ling, & Bartholomew, 2004; Heffernan, Ling, Parrott, et al., 2004; Heffernan, Ling, & Scholey, 2001; Heffernan et al., 2002; Ling et al., 2003; Rogers et al., 2001; Zakzanis et al., 2003).

Michigan Alcoholism Screening Test

The Michigan Alcoholism Screening Test (MAST; Selzer, 1971; see Appendix E) provides a brief screening instrument for the detection of problems related to alcohol use. Total scores exceeding 4 indicate the likely presence of alcohol abuse. The instrument has adequate reliability (Skinner & Sheu, 1982) and a low false negative rate (Selzer, 1971).

Drug Abuse Screening Test

The Drug Abuse Screening Test (DAST; Skinner, 1982; see Appendix F) is a brief self-report screening instrument for substance use history. The total score provides an indication of the severity of problems, with scores greater than five indicating the presence of drug abuse. The questionnaire has high reliability, distinguishes among types of treatment seekers (alcohol only, drug only, and alcohol/drug combined), and correlates with level of drug use (Skinner, 1982). Both the MAST and DAST provided an opportunity to assess the equality of the smoking and nonsmoking samples.

Shipley Institute of Living Scale

The Shipley Institute of Living Scale (SILS; Zachary, 1992) consists of items measuring vocabulary and abstraction skills providing as estimate of general intellectual functioning. For the present study, the vocabulary items were administered, consisting of 40 multiple-choice items asking participants to choose the most similar meaning word from the selection provided. Individuals are instructed to guess when they are unsure of an answer, and

the vocabulary test is limited to 10 minutes. One point is given for each correct item, and a correction for chance performance on unanswered items is included.

Modified CAGE

The 4-question CAGE screener (Mayfield, McLeod, & Hall, 1974) was modified to address both current drug and alcohol use in the community sample (see Appendix G). Callers endorsing current alcohol and/or drug use were administered the 4-question screener. Callers with a positive response to any of the 4 questions were excluded from the study. While this method screened current use, we did not screen for prior use and high levels of past substance and alcohol use are evident in the MAST and DAST scores.

Biochemical Measure

A carbon monoxide (CO) sample was taken using Vitalograph BreathCO machines, measuring the carbon monoxide content in exhaled air in parts per million (ppm). CO samples allow for verification of self-report smoking status by measuring exposure to CO within the previous eight hours. This permits detection of participants who may misrepresent their smoking status, and more importantly allowed the experimenter to verify compliance for the abstinence condition. The following cut-off values were established for the current study: nonsmokers < 6, deprived smokers < = 8, and nondeprived smokers > = 10. Although cotinine is regarded as the optimal measure of nicotine exposure, CO is a frequent alternative because the ease of use, reduced expense, and lack of involvement of bodily fluids (Velicer, Prochaska, Rossi, & Snow, 1992). Specificity estimates range from 80-85%, and specificity from 84-98% (Velicer et al., 1992). Rates of false negatives from studies using CO have ranged from 4.4-18.34% with the majority falling around 5%, and are higher than the false negative rates for cotinine samples (Velicer et al., 1992).

Cue-reactivity Paradigm and Urge/craving Measure

Cue-reactivity studies attempt to manipulate cravings through exposure to drug-related cues. Studies using in vivo manipulation for smokers typically have the participant take a cigarette out of a favored brand pack, hold, and light the cigarette (Sayette & Hufford, 1994). Video cues (Shadel, Niaura, & Abrams, 2001) and scripts (Conklin & Tiffany, 2001; Drobes and Tiffany, 1997) have also been effective in eliciting cravings to smoke. Imagery studies have also investigated the effect of affective content, finding negative affect scripts produce cravings even without urge content (Tiffany & Drobes, 1990) possibly reflecting the importance of negative affect in the relapse process.

Self-reported cravings, or urges, are often measured by use of visual analogue scales (VAS; Tiffany & Drobes, 1990), where participants rate the subjective experience of craving according to anchors (i.e., from none to worst ever). Likert-type scales (Niaura et al., 1999; Shadel, Niaura, & Abrams, 2001), ratings (Sayette & Hufford, 1994), or questionnaires (Drobes & Tiffany, 1997; Conklin & Tiffany, 2001; Taylor, Harris, Singleton, Moolchan, & Heishman, 2000) targeting craving have also been used with success. Other measures of cue reactivity concern the physiological changes occurring in withdrawal and may include heart rate, skin conductance, finger temperature, facial EMG, or arterial blood pressure.

Importantly, the construct of craving has been shown to predict lapse/relapse (Abrams et al., 1988; Doherty, Kinnumen, Militello, & Garvey, 1995; Shiffman, Engberg, et al, 1997). Doherty et al. (1995) assessed predictors of relapse at four time points (days 1, 7, 14, and 30) following cessation. Participants with greater reported urges were more likely to have relapsed by the next time point (Doherty et al., 1995). Strongest urges were reported one day following cessation, a sensitive period as many relapses occur in the first week of abstinence (33% relapsed in first 7 days in Doherty et al., 1995 study).

For the current study, an *in vivo* craving induction was included to increase the likelihood of engaging nonautomatic processes (Tiffany, 1990). Additionally, states of both high craving and withdrawal more closely resemble the situation encountered by smokers in high-risk situations following cessation. As noted previously, the constructs of craving and withdrawal, although commonly co-occurring, appear to be independent (APA, 1987; APA, 1994; Tiffany, 1990). As such, the 24-hour deprivation was used to induce nicotine withdrawal, and cue-reactivity was added to ensure high states of craving. A 120 mm VAS (see Appendix H) was used to measure craving for a cigarette at five time points: prior to cue-reactivity paradigm, following cue-reactivity task, following the LDT task, following the EBT task, and following the TBT. Participants were asked to place a vertical mark indicating the level of their current urge to smoke based on the anchors, 'No Urge to Smoke' to 'Worst Urge Ever Experienced.' Craving induction was accomplished by asking participants to hold a cigarette of their preferred brand and a lighter. Participants were not permitted to light the cigarette, but were encouraged to hold the cigarette and lighter as though they were preparing to smoke. Additionally, smokers were asked to think about the pleasant sensory aspects of smoking for a period of 2 minutes.

Although some arguments have been presented for the distinction between 'urge' and 'craving' (see Kozlowski & Wilkinson, 1987), the evidence suggests that these terms are interchangeable (Shiffman et al., 1997; Tiffany & Drobes, 1991; Tiffany, Singleton, Haertzen, & Henningfield, 1993). Therefore, the current paper will assume these terms are measuring the same construct.

Lexical Decision Task

The lexical decision task (LDT) presented word/nonword letter strings using EPrime software (Schneider, Eschman, & Zuccolotto, 2002) in a random sequence for each

participant. Participants were asked to make a word/nonword judgment as quickly and accurately as possible for each trial. Sixty trials were presented, with each trial lasting 3 seconds and the entire LDT duration of 3 minutes. Each trial consisted of a fixation point (an asterisk) that appeared for 250 milliseconds, followed by the presentation of the letter string for 2750 milliseconds. Participants responded to the letter strings by pressing the "yes" or "no" keys. The 'M' key was covered with a sticker indicating "no", and the 'Z' key indicated "yes". Regardless of the speed of the response, the trial interval from onset of the fixation point until the presentation of the next fixation point lasted 3 seconds. In order to preserve this trial length consistency, the letter string remained on screen following the participant's response until the 2750 millisecond presentation period ended. All letter strings were presented one at a time in 18-point font, in upper case format. All letter strings were between five and eight letters in length. Words were of medium frequency, and all nonwords were pronounceable. The computer recorded all letter string judgments and reaction times.

The use of task which measures reaction time permits evaluation of several hypotheses. First, comparison between the LDT and intention-embedded tasks will provide information regarding changes in cognitive demand from baseline to intention conditions. Slower reaction times are predicted for tasks involving intentions, due to increased task interference as a result of intention maintenance demands (Hicks et al., 2005). Second, Tiffany's (1990) cognitive processing model posits reaction time as an objective measure of cue reactivity. All smokers will receive the craving inducement procedure. Thus, comparisons between high craving/nondeprived and high craving/deprived conditions will provide information regarding possible additive demands of craving and withdrawal on cognitive resources as measured by reaction time. The second hypothesis will build upon the findings of Sayette and Hufford (1994).

Event-based PM Task

The event-based PM task (EBT) involved the same LDT asking participants to respond with word/nonword judgments; however, an intention was added by asking participants to respond to animal words by pressing the unlabeled space bar. No instruction was given regarding whether to make the LDT response on the PM trials, and neither task was emphasized as more important. The PM intention was selected based on likelihood of resulting in task interference (a proxy measurement of cognitive resource demands). Rather than using a specific cue, which would engage spontaneous retrieval processes, a nonfocal prompt was chosen for the PM intention (Einstein & McDaniel, 2005; Hicks et al., 2005). Focal prompts occur where the ongoing task is expected to facilitate processing of the prompt, thus making a spontaneous retrieval process more likely (Einstein & McDaniel, 2005). "Respond to the word *cat"* is an example of a focal prompt, whereas "Respond to words from the category *animal"* is an example of a nonfocal prompt (examples from Einstein & McDaniel, 2005). This same nonfocal category, animal words, was utilized in the current study. The exemplar 'dog' was given to participants in the instruction set. Of the total 140 new letter string trials presented in the EBT, three presentations of an animal word appeared ('monkey', 'horse', and 'rabbit'). The PM prompts occurred on trials 40, 80, and 120. The same parameters for letter strings and presentation of trials were maintained for the EBT. The number of false alarms (FA's) was calculated, representing the number of target presses that did not occur with the presentation of the PM prompt.

Time-based PM Task

A time-based PM task (TBT) was included to assess the occurrences of PM where more internal-based monitoring is used. It is hoped that the TBT mimics the internally-cued states (i.e., changes in affect) that may trigger relapse in smokers. Again, participants were

asked to engage in an LDT with previously unseen letter strings. The time-based PM intention was to press the space bar every 2 minutes. In order to provide access to a clock, a different software was used for the task TBT, and because of program differences, some parameters were modified from the previous tasks. For the TBT, a focal asterisk appeared for 2 seconds, and letter strings disappeared only following a response. The focal asterisk duration was increased in an attempt to hold the total length of the trial similar to that in the previous tasks, where each trial length was 3 seconds. Letter strings were presented in 27.25 font. The entire task lasted approximately 7 minutes with 140 letter string trials, and included three possible PM trials (at minutes 2, 4, and 6). PM responses were acknowledged by a small window appearing in the center of the screen for 1 second providing the message "Ok.." Any response within a 10-second window of the target time was accepted as correct responses (i.e., any response between 01:55 min and 02:05 min would be accepted as on-time). Participants had the option to monitor the passage of time by pressing the 'L' key, labeled 'clock'. The clock started at 00:00 and counted minutes and seconds passed since the start of the program. The clock appeared for 5 seconds in the center of the screen, and would disappear automatically or participants could hit the enter key in order to remove the clock in a more timely manner. Reaction times for the LDT task were excluded for trials where the clock was accessed or the target ('space bar') was pressed, as well as the following trial, in the calculation of the average reaction times to prevent artificial inflation of the mean reaction times because the windows inhibited response to the LDT. The clock was accessible for the entire task, and participants were free to utilize this option as much or as little as desired. The computer recorded the number of times the clock was accessed, as well as the time the access occurred.

Distracter Activity

The distracter involved pictures that had been divided into nine pieces and scrambled. The task was presented as a problem-solving activity, and participants were asked to complete each puzzle by reassembling the pictures as quickly as possible. Only the space bar and arrow keys were used for the distracter task. After a picture was correctly assembled, the computer presented the additional puzzles until completion of the 4-minute distraction period. The number of puzzles solved was dependent on the individual participant; some completed numerous puzzles while others completed only 1-2 puzzles. However, the number of puzzles completed was not recorded. The distracter was presented twice, following the presentation of the intention instruction sets for the event- and time-based tasks.

Procedure

Qualified community participants were asked to give informed consent over the phone. Participants from the student subject-pool completed the screening in person, and qualified individuals were scheduled for the experimental session. Smokers were randomly assigned to either smoke as usual or abstain for 24-hour conditions, while nonsmokers did not receive any instructions regarding smoking habits. Appointments were scheduled roughly 24 hours following the initial screening call. Upon arriving for a scheduled appointment, participants completed the SSQ, the PANAS, the MNWS, provided a CO sample, and completed the baseline craving measurement. Smokers in the deprived condition who exceeded the maximum CO reading marking abstinence were asked to reschedule. Next, a cue-reactivity paradigm intended to increase craving was given to smokers (both deprived and nondeprived). Smokers were asked to hold a cigarette and lighter, and to imagine smoking the cigarette for a period of 2 minutes focusing heavily on the sensory aspects of smoking. Nonsmokers did not receive any reactivity tasks. A second craving measurement was taken,

and then participants received instructions for the LDT. The baseline measurement of the LDT assessed reaction time when no PM intention had been given.

Following the baseline LDT, instructions for the EBT were given (press space bar every time an animal word is presented), and participants then completed the distracter task. Following the distracter, participants completed a third craving measure, and then were directed to begin the LDT. No reminder of the PM intention was given.

Following completion of the EBT, instructions for the TBT was presented asking participants to press the space bar every two minutes. Participants were also told that a clock was available to monitor the passage of time. Participants pressed the enter key to indicate they were ready, and the instructions for the distracter task appeared for a second time. The same distracter was presented for a 4-minute interval. Following the distracter task, the TBT began without any further reminders regarding the time-based intention. A craving measure was given at the beginning and end of the time-based task. Following the PM tasks, participants completed the remaining questionnaires and were debriefed. See Table 4 for a sequence of included activities.

Table 4

Sequence of Activities

Activity	Notes
Screening and condition assignment (deprived or nondeprived)	Smokers only
SSQ, PANAS, MNWS, CO, baseline craving	Scheduled approx. 24 hrs. following screening
Cue reactivity	Smokers only; 2 minutes
2nd craving measurement	
LDT	3 minutes
Instructions for EBT	
Distracter	4 minutes
3rd craving measurement	
EBT	7 minutes
Instructions for TBT	
Distracter	4 minutes
4th craving measurement	
TBT	7 minutes
5th craving measurement and remaining questionnaires (PMQ, MAST, DAST, Shipley)	
Debriefing	

Notes. SSQ = Smoking Status Questionnaire, PANAS = Positive and Negative Affect Schedule, MNWS = Minnesota Nicotine Withdrawal Scale, CO = carbon monoxide, LDT = Lexical Decision Task, EBT = Event-based Prospective Memory Task, TBT = Time-based Prospective Memory Task, PMQ = Prospective Memory Questionnaire, MAST = Michigan Alcohol Screening Test, DAST = Drug Abuse Screening Test.

Data Analysis

Data Analytic Strategy

For the computerized tasks, data (including reaction times, word/nonword responses, false alarms, etc.) from the first five trials were excluded in calculations to permit participants to adapt to the task demands. Any responses with reaction times less than 300 ms were excluded as these were likely anticipatory actions rather than true decisions. To reduce the interference of responding to PM prompts on reaction times, for both the EBT and TBT calculations of reaction time did not include the trials where the space bar was pressed. For the TBT, the trials where the clock was accessed were also not utilized in the calculation of reaction times. Finally, because of the design features of the TBT, the trials immediately following the clock or PM response were not used in calculating reaction times because the response message window may have precluded the LDT response.

For reaction times, participants' responses were trimmed by excluding any reaction times greater than 2.5 standard deviations above the individual's mean speed of performance. The mean of the remaining reaction times were calculated for each individual for variables of interest (e.g., reaction time for words, reaction time for nonwords). These adjusted variables are referred to as trimmed mean reaction times for the remainder of the paper.

PM performance was calculated as the proportion correct out of three possible responses for each PM task (EBT and TBT). Consistent with practice in other published studies of PM, a decision was made not to transform the proportions.

Participant's individual data consisting of each of the trials for the LDT, EBT, and TBT was reviewed for potential problems. This process resulted in the deletion of several participants' data for improperly completing the task (e.g., neglecting the LDT and only responding to the animal words) or program problems such as the program terminating

prematurely. Such problems were more evident with the TBT task where the final count of usable TBT data was reduced from 121 to 79 participants, the result of mostly computer program errors. Because the problems with the C+ program appeared to occur randomly throughout data collection and for both data collection sites, there is no reason to think these problems resulted in any systematic excluding of participants or interfered with randomization in any way. However, this did impact the number of complete data sets available for within-subjects analyses. Two deletions from self-report PM subscales (long-term and short-term) were made due to detection of univariate outliers.

Additionally, there were large differences in the programmed task elements of the TBT compared to the LDT/EBT. The decision to use C+ was guided by the necessity of having a clock available to participants; however, this program change interfered with the continuity of the tasks. Thus, it is quite possible that differences such as reaction time from the EBT to TBT are the result of program demands rather than task-specific effects. To account for this possibility, most within-subject comparisons are conducted with only the LDT and EBT data where all variables except the task demands were controlled. It should be noted, however, that the PM performance comparisons are made across program differences, and limit the ability to fully eliminate the program confound.

A decision to report analyses without the use of covariates was made based on lack of sufficient power and guided by the consistent presence of smoking status effects on PM above and beyond the impact of covariates (i.e., other drug/alcohol use) in other studies. However, this is a notable limitation of the current study, and firm conclusions regarding the relative impact of overall drug exposure versus impairment attributable to smoking on PM performance will await studies including larger samples of smokers.

Where hypotheses indicated directionality, one-tailed tests were used. Otherwise, two-tailed tests were reported. All dependent variables were assessed for violations of homogeneity of variance or spherecity. When violations were evident, corrected statistics were reported. For post-hoc analyses, when variances were not equal across groups, the Games-Howell procedure was used for comparisons. Otherwise, Tukey's B post-hocs were used. Lastly, three-group smoking status (nonsmoker, deprived smokers, and nondeprived smokers) comparisons are presented along with two-group smoking status (smoker, nonsmoker) comparisons of the same material.

Power Analysis

Estimated effect size was chosen using a recent meta-analytic analysis of PM and aging (Henry, MacLeod, Phillips, & Crawford, 2004). Of the three effect sizes provided (corresponding to strategic, laboratory time-based, and laboratory event-based tasks), the smallest ($r = -0.34$) was chosen for the current study in order to maximize chances of finding an effect. This value corresponds to an effect size estimate $f = 0.36$ (Buchner, Erdfelder, & Faul, 1997). Alpha was set at 0.05, and minimum acceptable power was 0.80. With three groups and the above parameters, total expected sample size was calculated using GPower (Erdfelder, Faul, & Buchner, 1996; Faul & Erdfelder, 1992), providing a recommended sample size estimate of 78 ($n = 26$ per group).

Results

Participant Characteristics

One-way analyses of variances (ANOVAs) indicated significant differences in means among the three smoking status groups for age, $F(2, 94) = 5.38$, $p = 0.006$, MAST scores, $F(2, 116) = 13.95$, $p < 0.001$, and DAST scores, $F(2, 117) = 32.42$, $p < 0.001$. No differences between smoking status groups were present for Shipley vocabulary scores, $F(2, 115) = 0.20$, $p = 0.83$, and this pattern was maintained when comparing the collapsed smoking category to nonsmokers, $t(27.98) = 0.03$, $p = 0.98$. For age, significant differences were present between nonsmokers and nondeprived smokers. For MAST scores, the only significant difference among the groups was between nonsmokers and nondeprived smokers. For DAST scores, nonsmokers and deprived smokers were significantly different.

Independent t-tests were used to compare years smoking, daily smoking rate, and dependence ratings between the smoker groups. No differences were present between deprived and nondeprived groups for daily smoking rate, $t(24) = 1.58$, $p = 0.13$, or dependence rating, $t(24) = 1.51$, $p = 0.15$; however, deprived smokers had been smoking for fewer years ($M = 7.62$, $SD = 5.71$) than nondeprived smokers ($M = 17.63$, $SD = 12.21$). Means and standard deviation for the above comparisons by group status can be found in Table 3.

To investigate potential differences in the frequency distributions of categorical descriptive variables, chi-square tests of independence were used. However, because of small observed and expected counts, the smoker groups were collapsed. It should be noted that visual inspection of the cell counts showed no apparent differences between the two smoker groups. Significant differences in the distribution of frequencies for smoking status were present for sex by smoking status (nonsmoker vs. smoker), a large percentage of the

nonsmokers were female (84%); however, the pattern was reversed for smokers where males were predominate (74%). Significant differences were present for ethnicity by smoking status. The distribution of Caucasian and African American was stable across smoking status, however, nonsmokers contained the only responses from individuals who represented themselves as "Other."

Manipulation Checks

Compliance was assessed by comparing CO measurements, self-reported withdrawal, and affect ratings across smoking status groups. Means for CO were significantly different across smoking status groups, $F(2, 110) = 190.08$, $p < .001$. Post-hoc analyses indicated all three group means were significantly different from one another in the expected pattern (mean CO for deprived smokers was below the criteria, and nonsmokers fell well within the nonsmoking range for CO readings). Mean withdrawal scores were also different between groups, $F(2, 118) = 32.40$, $p < .001$. Both smoker groups were significantly different from one another; however, nonsmokers were significantly different from deprived smokers but not nondeprived smokers. Self-reported positive affect was equivalent across the three groups, $F(2, 118) = 1.56$, $p = .21$, and this pattern was maintained in the 2-group smoker/nonsmoker comparison. Significant differences between nonsmokers and deprived smokers were present for negative affect, $F(2, 118) = 15.21$, $p < .001$. Means and standard deviations for CO, withdrawal, positive affect, and negative affect by smoking status are presented in Table 3.

In Figure 1, the mean VAS ratings for each MNWS item are presented, grouped by smoking status. As can be seen, some items exhibited considerable variability across smoking status groups. In particular, nonsmokers endorsed higher levels of hunger and sleep disturbance, and nondeprived smokers reported near equivalent levels of sleep disturbance as deprived smokers. Impatience/restlessness, anxiety/nervousness, and

anger/irritability/frustration items appear to hold the most promise for distinguishing patterns of withdrawal from everyday variability in symptoms.
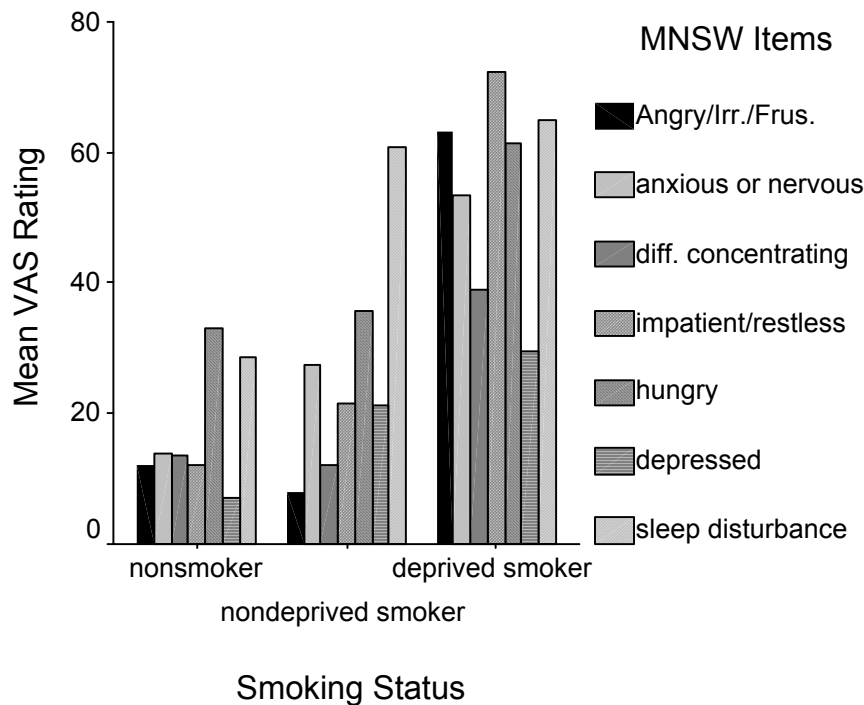

Figure 1. Mean Ratings for Minnesota Nicotine Withdrawal Scale (MNWS) Items by Smoking Status.

Cue-reactivity

Five craving measurements were taken in order to measure level and consistency of craving over the course of the experiment. The initial measurement represented the baseline craving rating; all other ratings occurred following the cue reactivity task. Any missing values on the craving measurements were replaced by calculating the mean of the surrounding data points. Of interest for examining the impact of the cue reactivity procedure was the level of craving among the groups and the stability of craving over time.

A mixed factors 5 (time) X 3 (smoking status) ANOVA revealed significant differences in craving ratings were present across the five time points, $F(2.62, 309.64) = 43.98$, $p < 0.001$,

and between the smoking conditions, $F(2, 118) = 255.81$, $p < 0.001$. A significant interaction of time and condition was also present, $F(5.25, 309.64) = 24.71$, $p < 0.001$. Within-subject contrasts suggested the presence of an order 4 polynomial trend for craving ratings over time, $F(1, 118) = 6.79$, $p = 0.01$; however, the interaction trend was significant for a cubic trend, $F(2, 118) = 14.35$, $p < 0.001$. Because the polynomial trend at each condition was of particular interest, these significant effects were followed up by assessing for trends in each smoking group individually. As craving among the nonsmokers was not of interest and remained low throughout the experiment (below 1.0 across all five time points), this group was not assessed separately. Deprived smokers reported high levels of craving throughout the five assessments (range of means: 89.68-101.25), and made no noticeable increases over time, $F(2, 52) = 1.43$, $p = 0.26$. As would be expected, no significant trends were present. For nondeprived smokers, significant effects of time were present, $F(1.84, 20.21) = 9.48$, $p = 0.002$, with a significant cubic trend, $F(1, 11) = 6.79$, $p = 0.024$. Baseline craving was low ($M = 30.79$, $SE = 3.91$), and increased following the cue reactivity task ($M = 52.67$, $SE = 4.90$). Craving remained level until the last measurement which showed an increase in mean rating ($M = 69.75$, $SE = 4.81$). Figure 2 depicts the level of craving for the three smoking status groups over the five assessment points.

Task Variables

LDT Performance

The proportion of correct lexical decisions (correct responses to words and nonwords) was compared across smoking status for the three task conditions. The within-subjects main effect for task was not significant (LDT: $M = 0.97$, $SE = 0.01$, EBT: $M = 0.97$, $SE = 0.01$, TBT: $M = 0.97$, $SE = 0.01$), Wilk's $\lambda = 0.99$, $F(2, 68) = 0.66$, $p = 0.66$, partial $\eta^2 = 0.01$. However, the between-subjects main effect of smoking status was significant (deprived

62

smokers: $M = 0.95$, $SE = 0.01$, nondeprived smokers: $M = 0.98$, $SE = 0.01$, nonsmokers: $M = 0.98$, $SE = 0.004$), $F(2, 69) = 6.94$, $p = 0.002$, partial $\eta^2 = 0.17$. A significant interaction was present, Wilk's $\lambda = 0.86$, $F(4, 136) = 2.67$, $p = 0.04$, partial $\eta^2 = 0.07$. Nonsmokers (LDT: $M = 0.98$, $SE = 0.01$, EBT: $M = 0.98$, $SE = 0.004$, TBT: $M = 0.99$, $SE = 0.01$) and nondeprived smokers (LDT: $M = 0.98$, $SE = 0.01$, EBT: $M = 0.97$, $SE = 0.01$, TBT: $M = 0.98$, $SE = 0.01$) appeared to maintain stable levels of correct responding across task types. However, deprived smokers demonstrated more variable and lower overall levels of performance in correct decisions across tasks (LDT: $M = 0.94$, $SE = 0.01$, EBT: $M = 0.96$, $SE = 0.01$, TBT: $M = 0.95$, $SE = 0.01$).
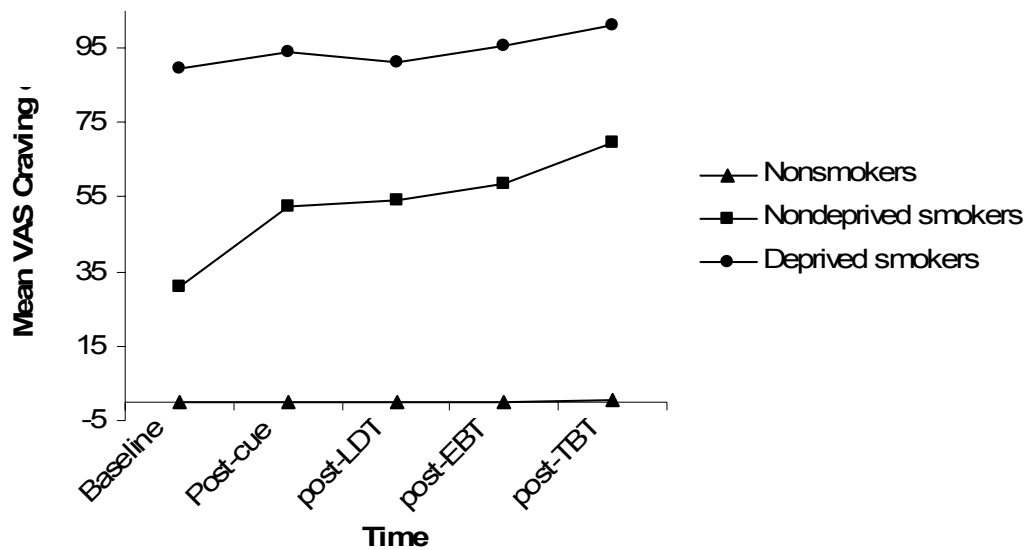

Figure 2. Mean Craving Measurements Over Time by Smoking Status Groups.

Self-report PM

    The three PM subscales of the PMQ were assessed for comparison of means between smoking status groups using a multivariate-ANOVA (MANOVA). Two participants were excluded from analyses as the presence of multivariate outliers was identified. The

assumption of homogeneity of variance-covariance matrices was violated and may affect Type 1 error. A significant effect of smoking status was present for the combined DV's, Pillai's Trace = 0.21, $F(6, 224) = 4.36$, $p < 0.001$, partial $\eta^2 = 0.11$. Follow-up tests of between-subjects effects found significant differences between smoking status groups for long-term PM, $F(2, 113) = 5.35$, $p = 0.006$, partial $\eta^2 = 0.09$, and short-term PM, $F(2, 113) = 10.91$, $p < 0.001$, partial $\eta^2 = 0.16$. The between-subjects effect for internally-cued PM was marginally significant, $F(2, 113) = 2.85$, $p = 0.06$, partial $\eta^2 = 0.05$. Bonferroni posthoc analyses indicated that nonsmokers and nondeprived smokers had significantly different means for long-term PM. For short-term PM, both smoking groups had high mean PM errors compared to nonsmokers, but the smoking groups were not different from one another.

A one-way ANOVA indicated that the groups were equivalent in the use of memory strategies, $F(2, 117) = 0.29$, $p = 0.75$. Means and standard deviations for the PM subscales and memory strategies by smoking status group are presented in Table 5.

Repeating the comparisons using the 2-group smoker/nonsmoker categorization, a similar pattern emerges of differences in PM errors in everyday living between smokers and nonsmokers, Pillai's Trace = 0.17, $F(3, 112) = 7.89$, $p < 0.001$, $\eta^2 = 0.17$. Smokers demonstrated a higher mean number of errors for long-term PM, $F(1, 114) = 6.86$, $p = 0.010$ (smokers: $M = 2.80$, $SD = 1.00$; nonsmokers: $M = 2.27$, $SD = 0.86$), short-term PM, $F(1, 114) = 21.96$, $p < 0.001$ (smokers: $M = 1.52$, $SD = 0.48$; nonsmokers: $M = 1.19$, $SD = 0.24$), and internally-cued PM, $F(1, 114) = 5.36$, $p = 0.022$ (smokers: $M = 3.15$, $SD = 1.32$; nonsmokers: $M = 2.56$, $SD = 1.06$).

Table 5

Means and Standard Deviations for Prospective Memory Indices by Smoking Status

	Nondeprived Smokers	Deprived Smokers	Nonsmokers	Total
Event-based PM	0.50 (0.48)	0.64 (0.39)	0.71 (0.40)	0.66 (0.41)
Time-based PM	0.36 (0.44)	0.39 (0.42)	0.52 (0.43)	0.47 (0.43)
Long-term PM*[+]	3.18 (1.01)	2.48 (0.92)	2.27 (0.86)	2.38 (0.91)
Short-term PM*[+]	1.54 (0.59)	1.51 (0.38)	1.19 (0.24)	1.26 (0.33)
Internally-cued PM[+]	3.30 (1.39)	3.02 (1.30)	2.56 (1.06)	2.68 (1.14)
Memory Strategies	3.42 (1.37)	3.54 (1.87)	3.78 (1.81)	3.72 (1.77)

Notes. PM = Prospective Memory, *Denotes significant difference between nondeprived smokers, deprived smokers, and nonsmokers ($p < .05$). [+]Denotes presence of significant differences between smokers and nonsmokers ($p < .05$).

Computerized PM Performance

A 3 (smoking status) X 2 (PM task type) mixed factors ANOVA was performed using the proportion of correct PM responses as the dependent variables (DVs). A significant main effect was present for PM task type, Wilk's $\lambda = 0.91$, $F(1, 73) = 7.03$, $p = 0.01$, partial $\eta^2 = 0.09$. Event-based PM performance ($M = 0.62$, $SE = 0.06$) was better than time-based PM performance ($M = 0.42$, $SE = 0.06$). Smoking status, $F(2, 73) = 1.60$, $p = 0.21$, partial $\eta^2 = 0.04$, and the interaction, Wilk's $\lambda = 1.0$, $F(2, 73) = 0.15$, $p = 0.86$, partial $\eta^2 = 0.004$, were not significant. Means and standard deviations for the PM performance by smoking status are presented in Table 5. The number of false alarms was equivalent across PM tasks (EBT: $M = 0.27$, $SE = 0.06$, TBT: $M = 0.39$, $SE = 0.13$), $F(1, 74) = 0.84$, $p = 0.36$, and between smoking status groups (deprived smokers: $M = 0.46$, $SE = 0.15$, nondeprived smokers: $M = 0.21$, $SE =$

0.15, nonsmokers: $M = 0.33$, $SE = 0.07$), $F(2, 73) = 0.73$, $p = 0.49$. No interaction was present, $F(2, 73) = 2.08$, $p = 0.13$. The number of times the clock was accessed was equivalent across deprived smokers ($M = 9.83$, $SD = 9.49$), nondeprived smokers ($M = 7.58$, $SD = 6.01$), and nonsmokers ($M = 9.84$, $SD = 8.38$), $F(2, 79) = 0.38$, $p = 0.68$.

Repeating the analysis with the collapsed smoker groups resulted in a significant main effect of PM task type, Wilk's $\lambda = 0.89$, $F(1, 74) = 9.49$, $p = 0.003$, partial $\eta^2 = 0.11$. Participants' mean proportion of PM responses indicated better performance for the EBT ($M = 0.64$, $SE = 0.05$) compared to the TBT ($M = 0.45$, $SE = 0.05$). Nonsmokers ($M = 0.61$, $SE = 0.05$) and smokers ($M = 0.47$, $SE = 0.07$) were not significantly different, $F(1, 74) = 2.85$, $p = 0.10$, partial $\eta^2 = 0.04$. Nor was the interaction significant, Wilk's $\lambda = 1.0$, $F(1, 74) = 0.005$, $p = 0.95$, partial $\eta^2 = 0.00$. See Figure 3 for a graph of the proportion of PM responses for the EBT and TBT by smoking status. The number of false alarms was equivalent across PM tasks (EBT: $M = 0.23$, $SE = 0.06$, TBT: $M = 0.43$, $SE = 0.11$), $F(1, 74) = 2.56$, $p = 0.11$, and between smoking status groups (smokers: $M = 0.33$, $SE = 0.10$, nonsmokers: $M = 0.33$, $SE = 0.07$), $F(1, 74) = 0.003$, $p = 0.96$. No interaction was present, $F(1, 74) = 2.56$, $p = 0.11$. The number of times the clock was accessed did not differ between smokers ($M = 8.71$, $SD = 7.85$) and nonsmokers ($M = 9.84$, $SD = 8.38$), $F(1, 80) = 0.57$, $p = 0.57$. A graphical depiction of PM performance can be seen in Figure 3. Included in this graph are the three smoking status groups, plus the combined smoker group.

Relation of Self-report and Computer-assessed PM

No significant correlations were present between the EBT and the three self-report PM subscales of the PMQ: long-term, $r(90) = 0.05$, $p = 0.33$, short-term PM, $r(90) = 0.07$, $p = 0.27$, or internally-cued PM, $r(90) = 0.06$, $p = 0.28$. The same was true of the TBT and PMQ

subscales: long-term, $r(82) = -0.03$, $p = 0.38$, short-term PM, $r(82) = 0.13$, $p = 0.12$, or

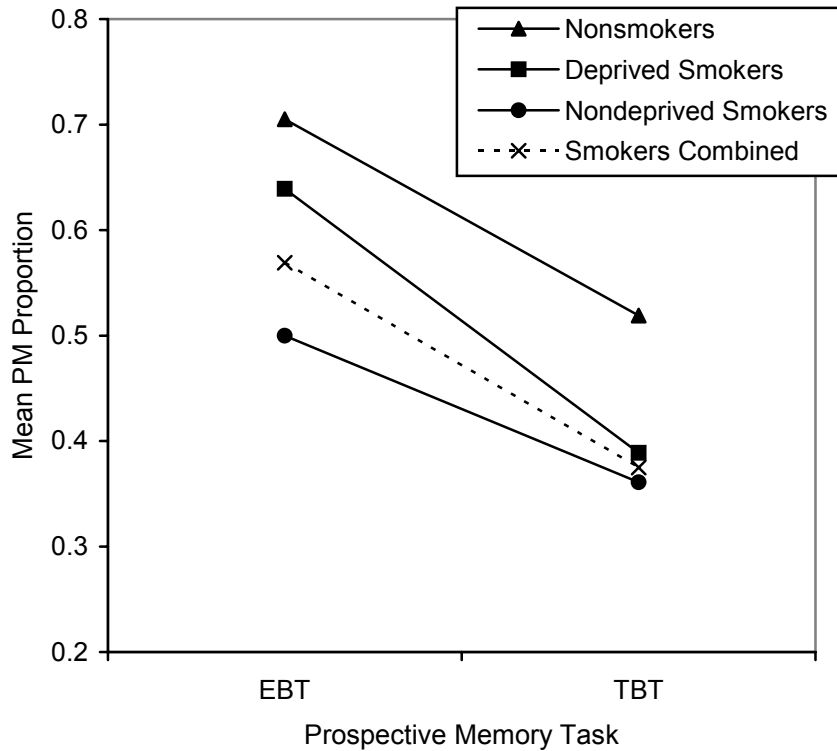internally-cued PM, $r(82) = -0.004$, $p = 0.49$.

Figure 3. Mean Proportion of Prospective Memory Responses by Smoking Status for the Event-based and Time-based Tasks.

PM and Affect

Significant correlations were observed between the PMQ subscales and affect. Long-term PM was significantly correlated with both positive, $r(120) = -0.31$, $p < 0.001$ and negative affect, $r(120) = 0.30$, $p < 0.001$. Short-term PM was significantly correlated with positive affect, $r(120) = -0.16$, $p = 0.04$, but not negative affect, $r(120) = 0.03$, $p = 0.36$. Internally-cued PM was significantly correlated with both positive, $r(120) = -0.27$, $p = 0.001$ and negative affect, $r(120) = 0.29$, $p = 0.001$. Memory strategies were not significantly

correlated with either positive, $r(120) = 0.07$, $p = 0.24$, or negative affect, $r(120) = 0.11$, $p = 0.11$. For the event- and time-based computerized measurements of PM, no significant correlations were present for either positive, $r(90) = -0.09$, $p = 0.19$, $r(82) = -0.14$, $p = 0.11$, or negative affect, $r(90) = -0.03$, $p = 0.39$, $r(82) = 0.08$, $p = 0.23$.

The above MANOVA analyses on the self-report PM subscales was repeated using a covariate to assess the impact of smoking status beyond that of negative affect. A significant effect of smoking status on the combined DV's remained present, Pillai's Trace = 0.12, $F(6, 218) = 2.39$, $p = 0.03$, partial $\eta^2 = 0.06$. The covariate, negative affect, was also significant, Pillai's Trace = 0.17, $F(3, 108) = 7.53$, $p < 0.001$, partial $\eta^2 = 0.17$. No significant interaction was present between the covariate and smoking status, suggesting the homogeneity of regression assumption was preserved. Follow-up univariate assessment of the between-subjects effects found that the covariate, negative affect, was significant for long-term PM, $F(1, 110) = 12.81$, $p = 0.001$, and internally-cued PM, $F(1, 110) = 10.42$, $p = 0.002$. Effects for smoking status remained only for short-term PM, $F(2, 110) = 5.98$, $p = 0.003$, where nondeprived smokers had significantly more errors than nonsmokers.

Reaction Time

Prompt Type. A mixed factors 3 (smoking status: nonsmokers, deprived smokers, and nondeprived smokers) X 2 (prompt type: word or nonword) ANOVA was performed using the trimmed mean reaction times from the LDT as DV's. A significant effect for prompt type was present, Wilk's $\lambda = 0.59$, $F(1, 91) = 62.30$, $p < 0.001$, partial $\eta^2 = 0.41$, where trimmed mean reaction time to words ($M = 718.28$, $SE = 21.98$) was faster than trimmed mean reaction time to nonwords ($M = 940.67$, $SE = 41.30$). No significant interaction was present between prompt type and smoking status, Wilk's $\lambda = 0.96$, $F(2, 91) = 2.11$, $p = 0.13$, partial $\eta^2 = 0.04$,. The between-subjects variable, smoking status, showed significantly different mean trimmed

reaction times across groups (deprived smokers: M = 935.11, SE = 59.59, nondeprived

smokers: M = 816.82, SE = 62.02, nonsmokers: M = 736.50, SE = 25.86), $F(2, 91)$ = 4.95, p =

0.01, partial η^2 = 0.10; however, Games-Howell post-hoc analyses failed to detect any

differences. The same pattern was evident for the EBT task comparison of trimmed reaction

times to prompt type across smoking status.

Prompt Type by Task Type Comparisons. Using the 2-group smoking status variable,

a 3-way analysis was performed. A mixed factors 2 (prompt type: word and nonword) X 2

(event type: LDT and EBT) X 2 (smoking status: smokers and nonsmokers) ANOVA was run

using trimmed reaction times as the DV's. Significant main effects were present for prompt

type, Wilk's λ = 0.59, $F(1, 86)$ = 60.82, p < 0.001, partial η^2 = 0.41 (Words: M = 747.59, SE =

17.48; Nonwords: M = 919.82, SE = 31.50), task type, Wilk's λ = 0.84, $F(1, 86)$ = 16.39, p <

0.001, partial η^2 = 0.16 (LDT: M = 806.03, SE = 26.05; EBT: M = 861.39, SE = 21.66), and

smoking status, $F(1, 86)$ = 10.86, p = 0.001, partial η^2 = 0.11 (Nonsmokers: M = 758.08, SE

= 24.47; Smokers: M = 909.34, SE = 38.85). Among the two-way interactions, prompt type by

smoking status was marginally significant, Wilk's λ = 0.96, $F(1, 86)$ = 3.24, p = 0.08, partial

η^2 = 0.04, task type by smoking status was not significant, Wilk's λ = 1.0, $F(1, 86)$ = 0.24, p =

0.63, partial η^2 = 0.003, and prompt type by task type was significant, Wilk's λ = 0.86, $F(1,$

$86)$ = 13.93, p < 0.001, partial η^2 = 0.14. The pattern of trimmed mean reaction times for the

marginally significant prompt type by smoking status interaction suggested that smokers

slowed more for nonwords than smokers. While both groups had slower reaction times for

nonwords compared to words, smokers slowed by an average of 211.96 ms (Words: M =

803.36, SE = 29.58; Nonwords: 1015.32, SE = 53.30) compared to average decrease in speed

of 132.50 ms for nonsmokers (Words: M = 691.82, SE = 18.64; Nonwords: 824.33, SE =

33.58). For the prompt type by task type interaction, the pattern of means suggested that the

addition of a PM intention slowed responding in general, but more so for words compared to

nonwords. For words, the difference between the LDT and EBT tasks was 90.43 ms (LDT: *M*

= 702.38, *SE* = 19.11; EBT: *M* = 792.81, *SE* = 18.57). For nonwords, the difference was

lessened to 20.30 ms (LDT: 909.67, *SE* = 35.75; EBT: 929.98, *SE* = 29.71). The three-way

interaction was not significant, Wilk's λ = 1.0, $F(1, 86)$ = 0.41, p = 0.53, partial η^2 = 0.01. See

Figure 4 for a graph of mean trimmed reaction times for words and nonwords for the baseline
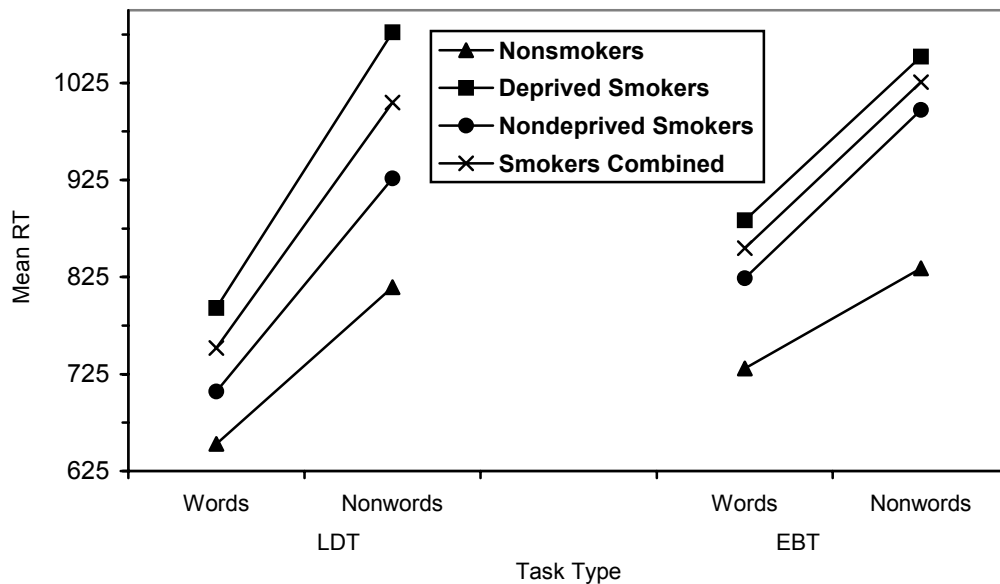
LDT and the EBT by smoking status.

Figure 4. Mean Trimmed Reaction Times for Lexical Decisions for Baseline and Event-based
Prospective Memory Tasks by Smoking Status.

Discussion

In addressing high rates of relapse that continue to be a significant problem in today's cessation programs, coping response execution failures have been identified as a possible contributor. Despite the fact that coping skills form the foundation of nearly every cessation program (Piasecki, 2006), very little research investigating failures to utilize coping skills has been conducted. In light of Brandon et al.'s (1990) study showing less than a third of relapsers reported having executed a coping response, this seems to be an important area to pursue. Building on the predictions posited by Tiffany's (1990) model, Sayette & Hufford (1994) note that depleted cognitive resources caused by craving and/or withdrawal may impair ability to attend to other tasks, particularly coping.

The current study applies a common cognitive psychology construct, PM, as a possible mechanism for explaining how these failures may occur. As noted by others (Brandon et al., 2004), PM has intuitive appeal for addressing coping responses and failures. Here, we compare smokers and nonsmokers on computerized and self-report assessment of PM performance. Based on the extant literature showing consistent deficits in substance users compared to nonusers in PM, we expect smokers to demonstrate more impairment in PM performance. Additionally, we are interested in whether nicotine withdrawal may further disrupt PM; however, conclusions regarding withdrawal were limited by sample size concerns.

The goal for establishing the deprived smoker condition was to mimic circumstances encountered by smokers during cessation (i.e., high withdrawal symptoms and high levels of craving). Cue reactivity was used to ensure high levels of craving prior to onset of the computerized tasks. In order to detect possible additive effects of craving and withdrawal, the nondeprived smokers also engaged in the cue reactivity task, and represented a high craving

but low withdrawal symptoms condition. Analyses of the craving measurements indicated that the cue reactivity paradigm was effective in raising craving ratings among smokers. However, the majority of increase in craving was seen in the nondeprived smokers. Deprived smokers initially reported high level of craving and maintained high levels of craving throughout the tasks. Thus, the cue reactivity task may not be necessary for deprived smokers in studies that focus exclusively on this subsample. For the current sample, it served the purpose of maintaining consistency across the smoker subsamples in exposure to stimuli and imagery.

Examination of the withdrawal symptoms inventory suggested the three groups differed in their symptom experience, with deprived smokers exhibiting the highest level of symptoms. These results suggest the 24-hour nicotine deprivation period was sufficient to cause noticeable difference in withdrawal symptomatology. Interestingly, considerable variability was evident across the three groups in withdrawal symptoms. Three items appeared particularly responsive to the 24-hour deprivation: anger/irritability/frustration, anxiety/nervousness, and impatience/restlessness.

Results suggest smokers differ from nonsmokers on long-term, short-term, and internally-cued PM as measured by the PMQ. These group differences did not carry over to the computerized tasks of PM, perhaps not surprising as these measurements of PM were not correlated with one another. Event-based PM performance was higher than time-based PM performance. However, the confound present because of the change of programs precludes the ability to draw any conclusions regarding the cause of this difference in performance between the two tasks. Both positive and negative affect were related to the PM-related PMQ subscales (but not memory strategies). Again, these significant relations were not present for the computerized PM assessments. This may be a reflection of the consistency of self-report formats for the PMQ and PANAS. The inclusion of negative affect as a covariate partially

mediated the impact of smoking status, suggesting the differences present between smokers and nonsmokers in negative affect are contributing to the higher rates of PM errors found in smokers.

There is some evidence to suggest that nicotine administration results in overestimation of time (Carrasco, Redolat, & Simon, 1998). In the same study, abstinent smokers were equivalent to nonsmokers, exsmokers, and nondeprived smokers in latency, but were significantly different from these groups in terms of absolute errors (Carrasco et al., 1998). In the present study, poor time estimation did not appear to be a negative influence on smokers performance. Groups were equivalent on the number of clock accesses, time-based PM responding, and number of false alarms.

Despite findings that craving and withdrawal contribute independently with an additive negative impact on memory (Mendrick et al., 2006; Sayette & Hufford, 1994), the results of the current study suggested withdrawal is not a negative influence on PM. Although sample size was small for smokers, the pattern of means for PM performance was consistent across all PM measures, and did not support this pattern. Across all five PM measurements, nonsmokers obtained the highest level of performance, and nondeprived smokers the lowest. It is unlikely that additional smokers would change the means to the degree necessary to show an impact of withdrawal on PM. Where nicotine withdrawal did appear to exert influence was in lower levels of correct lexical decisions, and more variable performance across the three tasks. In contrast, both nondeprived smokers and nonsmokers maintained high levels of performance consistently across the three tasks.

As expected, reaction time to words was consistently faster than reaction time to nonwords. Both smoking status and task type appear to interact with prompt type reaction times. Overall, nonsmokers demonstrated faster reaction times than smokers. As expected,

reaction times were faster when no intention was present compared to when the event-based intention was introduced reflecting the addition cognitive demand necessitated by maintaining an intention. The interaction of these variables revealed that smokers' reactions slow more than nonsmokers to words compared to nonwords. Additionally, although reaction times for nonwords overall were greater than words, the increases in reaction time for nonwords compared to words appears to be partially alleviated in the intention condition compared to the LDT.

Deprived smokers had smoked far fewer years compared to the smokers in the nondeprived condition. Given that random assignment to condition was used, it is possible that this difference is indicative of a systematic self-excluding from the deprived condition. That is, it appears that more heavily dependent smokers cancelled or failed to show for scheduled appointments in a systematic fashion for the deprived, but not the nondeprived, condition. This may be the result of more difficulty abstaining among these individuals, even for the brief period expected for the study.

A confound between the smokers and nonsmokers is present due to the cue reactivity task completed by smokers. It is possible that deficits in PM performance could be attributed to the engagement of imagery rather than to any effects of smoking. Future studies may wish to have nonsmokers complete an imagery task that is not specific to smoking to eliminate this confound.

Increasingly, researchers have begun emphasizing the importance of moving away from the current reliance on self-report measurement of addiction-related phenomenology (Brandon et al., 2004; McCusker, 2001; Tiffany, 1990; Tiffany, 1997; Tiffany, Conklin, Shiffman, & Clayton, 2004; Waters & Leventhal, *in press*). A strength of the current study is found in the inclusion of implicit and explicit measurement tools, permitting comparisons

between participants' response. Tiffany et al. (2004) noted that smokers may not understand the processes that contribute to smoking. Due to the automatic nature of the behavior, very little conscious effort is involved in drug use possibly leaving individuals at a loss to explain their own behavior (Tiffany, 1990). Thus, implicit measurements may provide another option of obtaining a clear picture of the smoking processes (Tiffany, 1990; Waters & Leventhal, *in press*).

The current study did not assess self-report of reminders. However, while some evidence suggests PM performance is correlated with self-reminders, the causes of this relation are not well understood (Guynn, McDaniel, & Einstein, 1998). The authors point out that high levels of self-reminders may drive increased performance in PM tasks, that good PM performance may prompt high levels of self-reminding, or the possibility that a third variable is responsible for increases in both factors. Attention to this component may be warranted in future studies, particularly as the findings have clinical relevance. For example, Guynn et al. (1998) found reminders containing reference to both the intended activity and the target event to be most helpful, and additional information/strategies (i.e., imagery) did not noticeably improve memory performance.

Although gender effects were not assessed in the current study, they may be an important consideration in the interpretation of withdrawal. Gender effects have been noted in self-reported withdrawal symptoms, where women report higher withdrawal symptoms (Leventhal et al., 2007; Jacobsen et al., 2004). However, although females report more symptoms, males exhibit greater impairment in tasks of attention, suggesting the subjective/objective nature of measurement will influence the direction of observed gender effects (Jacobsen et al., 2004). The authors noted the possibility that the observed deficits among males are due to greater neurotoxicity from an earlier age of smoking initiation

(Jacobsen et al., 2004). Additionally, future studies may include a nondeprived/low craving comparison group which would permit assessment of Tiffany's (1990) predictions regarding the role of cognitive processes in dependence. Future studies may wish to include such a comparison group to directly assess the impact of craving on cognition.

Given the evidence of a 'hardening' of the smoking population (Irvin & Brandon, 2000; Irvin et al., 2003; Piasecki, 2006), treatments will likely continue to decrease in their effectiveness. Treatment programs will need to be advanced and grow to address the needs of these smokers. The clinical relevance of prospective memory (Chasteen, Park, & Schwartz, 2001; Kliegel & Martin, 2003) is particularly appealing because of evidence of responsiveness to intervention. Although the evidence presented in this study suggests that withdrawal does not negatively impact PM performance, the results do point toward overall deficits in smokers compared to nonsmokers. Thus, it may be useful to include memory education or electronic memory aids to improve PM intention execution as has been done with the special populations noted above. PM differences in substance users versus nonusers presents an exciting new avenue for research with direct clinical relevance.

The rationale for this study was derived from both cognitive and clinical psychology concepts and theories. Bridging the cognitive/clinical domains will lead to better understanding of the complexities of behavior; and both domains will be strengthened by routinely incorporating information from other approaches (Roskos-Ewoldsen, 2006). The results suggest PM impairment is present in smokers compared to nonsmokers, but is not worsened by 24-hour nicotine withdrawal. The consistent presence of PM impairment in substance users may suggest a useful avenue for therapeutic intervention in treatment programs in addressing coping skills failures during cessation attempts.

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Appendix A

Modified CAGE

1) Have you ever felt you should cut down on your drinking/drug use?

2) Have people ever annoyed you by commenting on your drinking/drug use?

3) Have you ever felt guilty about your drinking/drug use?

4) Have you ever had to drink/use drugs first thing in the morning (an eye opener or early morning drink) to steady your nerves or to get rid of a hangover or residual drug effect?

Appendix B

Urge/Craving Scale

Participant ID: _____   Time # _____   Date: _____

What is your current urge to smoke a cigarette?

No Urge
to Smoke   _____
At All

Worst
Urge Ever
Experienced

Vita

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