REWARD MOTIVATION AS A MECHANISM LINKING PERSONALITY AND INTERMITTENT SMOKING

A Dissertation in Psychology

by

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Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

August 2015
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ABSTRACT

The negative public health impact of daily smoking has been well established over decades of empirical research. As such, traditional conceptualizations of nicotine addiction emphasize behaviors typically experienced by daily smokers such as withdrawal avoidance. Nondaily/intermittent smokers (ITS), a rising population with similar negative health consequences as daily smokers, have received comparatively little attention. Most notably, nondaily smokers exhibit comparable rates of cessation failure and number of quit attempts as daily smokers. Since nondaily smokers do not smoke on a regular basis, withdrawal avoidance is not likely to motivate smoking maintenance and cessation failure. Instead, nondaily smokers may be motivated by “peak seeking” or the acute rewarding effects of nicotine. Individual factors associated with sensitivity to rewarding stimuli can provide insight into potential mechanisms by which peak seeking motivates smoking behavior. The current study used a rewarded antisaccade task followed by a 7-day ecological momentary assessment period to evaluate the relationship between disinhibition traits, reward motivation, and momentary factors related to reward seeking and the subjective effects of nicotine. More specifically, the analysis tested the hypothesis that reward motivation mediates the relationship between disinhibition and momentary behavior. Results failed to support a mediational model; however, the results highlighted potentially important factors related to smoking behavior in ITS. Primary results suggest that ITS with greater disinhibition and reward motivation report higher momentary adventurousness after smoking a cigarette, but not during nonsmoking occasions. Therefore, within nondaily smokers, consideration of alternative factors that motivate smoking behavior may help better
conceptualize problematic smoking in this population. Additionally, relationships between personality, reward motivation, and momentary responses highlight the potential importance of studying co-occurring negative health behaviors in developing intervention strategies.
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INTRODUCTION

Cigarette smoking is one of the leading causes of preventable death in the United States (Center for Disease Control and Prevention [CDC], 1997), with health-related economic costs that exceed $193 billion per year (CDC, 2008). Accordingly, extensive tobacco research has focused on gaining a better understanding of the mechanisms that underlie the maintenance of cigarette smoking. The vast majority of this research has concentrated on individuals who smoke on a daily basis (typically those smoking $\geq 10$ cigarettes per day [cpd]; Brown, Manuck, Flory, & Hariri, 2006; Schane, Ling, & Glantz, 2010; Shiffman, Ferguson, Dunbar, & Scholl, 2012). On one hand, the emphasis on daily smokers is justified given the well-documented health consequences and high relapse rates associated with high levels of cigarette use. On the other hand, it is becoming increasingly clear that much can be gained from the study of nondaily smokers, a category of individuals that has received comparatively little empirical attention.

The number and pattern of cigarette consumption has commonly been used as a proxy for exposure to tobacco-related toxins, level of addiction, and risk of disease. One challenge in studying nondaily smoking lies in the variety of terms used to define smokers who consume a lower level of cigarettes. Particularly problematic is that these smokers may not self-identify as smokers, thus decreasing the probability of participating in smoking research. In an attempt to better characterize low-level smokers, Husten (2009) summarized multiple research studies that employed a range of terms to define light and nondaily smoking. The results highlighted a multitude of terms used in the literature, including “light smokers” (Bjartveit & Tverdal, 2005;
Shiffman, 2005), “very light smokers” (Shiffman et al., 1992), “chippers” (Shiffman, 1989; Shiffman, Kassel, Paty, Gnys, & Zettler-Segal, 1994), “occasional smokers” (J. R. DiFranza et al., 2000; Paavola, Vartiainen, & Puska, 2001), and “intermittent/nondaily smokers” (Lindstrom & Isacsson, 2002; W. J. McCarthy, Zhou, & Hser, 2001). Among these categories of use frequency, comparisons between daily and nondaily/intermittent smokers were deemed to be the most useful, with nondaily/intermittent smokers as the most stable and consistently defined category of low-level smoking (Husten, 2009). Nondaily smokers are also differentiated from daily smokers attempting to cut down on smoking frequency or trying to quit. For example, only 25% of long-term, stable, nondaily smokers have ever been a daily smoker (Hassmiller, Warner, Mendez, Levy, & Romano, 2003) and 87% of adult nondaily smokers still reported nondaily cigarette use after 1 year (Husten, McCarty, Giovino, Chrismon, & Zhu, 1998). In the following discussion, the terms nondaily and intermittent smokers (ITS) will be used interchangeably.

Recent research has defined ITS as individuals who endorse smoking on "some (but not all) days" with a lifetime cigarette count of over 100 cigarettes (Husten, et al., 1998; Shiffman et al., 2012; Tracy, Lombardo, & Bentley, 2012). Below is a summary of research demonstrating ITS are a rapidly growing, understudied population that, similar to their daily smoking counterparts, are at risk for significant negative health outcomes and problematic smoking behavior. In particular, many ITS demonstrate considerable difficulty quitting (Tindle & Shiffman, 2011) and report smoking behavior that highlights the potential importance of individual factors over traditional models of nicotine dependence (Shiffman, Dunbar, Scholl, & Tindle, 2012; Shiffman, Ferguson, et al.,...
Taken together, the mechanisms associated with smoking maintenance and addiction in ITS have significant implications for developing effective treatment interventions focused on sustained abstinence for this population.

**Intermittent smokers: A growing public health concern**

Recent national surveillance data have demonstrated a dramatic change in population smoking patterns. Nondaily smokers constitute approximately a quarter of adult smokers in the US (CDC, 2008; Substance Abuse and Mental Health Services Association [SAMHSA], 2009). Further, while rates of daily smoking have declined in the past decade, the number of ITS have increased by 40% in the US between 1996 and 2001 (CDC, 2003). This increase has been shown to be particularly prominent among young adults (those 18-25 years of age; SAMHSA, 2009; Pierce, White, & Messer, 2009). For instance, recent data indicate that over half of young adults who report smoking cigarettes are classified as nondaily smokers (Halperin, Smith, Heiligenstein, Brown, & Fleming, 2010; Lenk, Chen, Bernat, Forster, & Rode, 2009; Moran, Wechsler, & Rigotti, 2004). One common misconception among nondaily smokers is that intermittent smoking is a "safe level" of cigarette use (Schane, Glantz, & Ling, 2009; Weinstein, 1998). Findings from several studies clearly demonstrate that this assumption is false and that nondaily cigarette use is associated with numerous adverse health outcomes (Bjartveit & Tverdal, 2005; Schane, et al., 2010). For example, in a recent four-year study (n = 1,253) nondaily smoking was associated with self-reported poor health outcomes in young adults (Caldeira et al., 2012). Another longitudinal study reported that after 18 years of follow-up, nondaily smokers had comparable cardiovascular disease risk as light and heavier smokers (Luoto, Uutela, &
Puska, 2000). In addition, nondaily smoking during young adulthood is associated with increased prevalence of psychological problems, greater utilization of emergency services, high-risk behaviors, other substance use, alcohol consumption, and interpersonal difficulties (J. S. Brook, Ning, & Brook, 2006; Halperin, et al., 2010). Taken together, intermittent smoking in young adults is a growing problem that carries enormous public health implications.

**Smoking behavior and addiction in ITS**

While epidemiological studies generally have classified nondaily smokers as a unitary population, empirical research has suggested important variability within this group (Evans et al., 1992; Lenk, et al., 2009; Shiffman, Tindle, et al., 2012; Zhu, Sun, Hawkins, Pierce, & Cummins, 2003). Shiffman et al. (2012) reported that ITS consume an average of 4.85 cpd; however, the reported number of cpd ranged from 0 to 20, and exhaled carbon monoxide levels ranged from 0.67 to 50.38 (Shiffman, Tindle, et al., 2012). Based on these findings, it can be assumed that the environmental context and motivations for smoking cigarettes may vary within a population of nondaily smokers. The use of Ecological Momentary Assessment (EMA), in which behavior is repeatedly sampled as it occurs over time in participants’ natural environments, is a research technique that is ideally suited to capture potential heterogeneity in the smoking patterns of ITS.

The use of EMA as a data collection technique has several advantages to traditional survey assessment in a laboratory setting. In the addiction literature, the momentary state and situation context is a critical part of many treatment interventions (for example see: Larimer, Palmer, & Marlatt, 1999). Recently the use of EMA has been
successfully applied to nicotine addiction to obtain a finer grain analysis of lapses, relapse, and smoking behavior (Shiffman, 2014). For example, Shiffman et al. (2007) used EMA to measure mood and situational variables on smoking occasions and at randomly selected nonsmoking occasions in a population of daily smokers during a quit attempt. Comparing these two momentary data responses, it was reported that individuals who reported higher negative affect on smoking occasions compared to nonsmoking occasions were more prone to cessation failures. Most notably, this effect was not apparent using standard questionnaires measures of negative affect administered at a single time point (Shiffman et al., 2007). Due to the less regular smoking patterns of ITS, smoking behavior within a laboratory setting during a diurnal time that the individual may not usually smoke could provide unreliable data. Therefore, the ability to compare differences in momentary states at a specific time (i.e., after smoking a cigarette) within an individual smoker’s natural environment could yield more useful conclusions about smoking behavior.

In a recent EMA study that measured smoking behavior over a period of approximately 21 days, Shiffman et al. (2009) reported that ITS smoked an average of two out of three days (67%), but some ITS indicated smoking almost every day, while others smoked as little as two days per week. Additionally, exploration of the situational factors related to cigarette smoking revealed that only a small percentage of ITS were considered “social smokers” (Shiffman, Kirchner, Ferguson, & Scharf, 2009), thus dispelling the belief that ITS only smoke for affiliative reasons, and suggesting that a majority of ITS are likely motivated by factors related to nicotine addiction. By using EMA as a data collection method, the current study can use surveys with shared
response items to investigate differences in an individual’s daily life (i.e., nonsmoking occasions) and immediately after smoking a cigarette. In doing so, it is possible to investigate potential factors associated with smoking maintenance in nondaily smokers that are not well covered by current conceptualizations of nicotine addiction.

Nicotine addiction (i.e., dependence) has traditionally been viewed as the primary determinant of cigarette smoking. Nicotine addiction is a multidimensional syndrome that includes several facets that motivate smoking behavior, including sensitivity to the effects of nicotine, preference for the reinforcing effects of nicotine, and smoking to avoid withdrawal symptoms (Shiffman, Waters, & Hickcox, 2004). In particular, the avoidance of withdrawal is commonly regarded as a core feature of addiction (Benowitz, 2008; Shiffman, Ferguson, et al., 2012). That is, smokers are thought to use cigarettes throughout the day in order to maintain nicotine levels that diminish the experience of withdrawal symptoms (Benowitz, 2008). Withdrawal symptoms from nicotine addiction can significantly impair daily functioning and include irritability, anger, anxiety, difficulty with concentration, increased appetite, restlessness, depressed mood, and insomnia (American Psychiatric Association, 2013) and daily smokers frequently smoke to alleviate these symptoms. The compulsion to smoke to avoid withdrawal symptoms is thought to reflect a reduced capacity to control smoking behavior and correlates highly with overall nicotine dependence scores (Shiffman, et al., 2004). Given the reduced consumption of cigarettes in nondaily relative to daily smokers, the extent to which smoking behavior of ITS is motivated by alternative factors than those emphasized in traditional conceptualizations of nicotine addiction would increase understanding of motivators for nondaily smoking.
A small number of studies conducted during the past five years have suggested that symptoms of dependence can appear rapidly after the onset of smoking (DiFranza & Wellman, 2005; Scragg, Wellman, Laugesen, & DiFranza, 2008). Savageau et al. (2009) reported that diminished autonomy over tobacco use, defined by the authors as increased discomfort related to withdrawal, is an early indicator of the transition to dependence. These progressively worsening symptoms of diminished autonomy may appear after just a few cigarettes, with each successive cigarette diminishing the likelihood of eventual cessation (Savageau, Mowery, & DiFranza, 2009). Striking as these findings may be, other researchers have argued that these studies do not accurately reflect addiction during the onset of smoking behavior. Specifically, the dependence measure used in the above studies may emphasize sensitivity over specificity, resulting in an elevated number of “dependent” smokers (Shiffman, Ferguson, et al., 2012). Therefore, an emphasis on withdrawal avoidance may fail to capture the primary motivators of nondaily smoking behavior.

By adopting a broader conceptualization of tobacco dependence, recent research has highlighted clinically significant differences between daily smokers and ITS. Most notably, using a variety of traditional dependence measures, ITS are generally not considered nicotine-dependent. Compared to daily smokers, ITS score lower on a variety of well-established nicotine dependence measures including the Fagerstrom Test for Nicotine Dependence (FTND), Nicotine Dependence Syndrome Scale (NDSS), Time to First Cigarette (TTFC), and the Wisconsin Inventory of Smoking Dependence Motives (WISDM) (Shiffman, Ferguson, et al., 2012). Of these measures, the WISDM includes two subscales of dependence: primary and secondary
dependence motives (Piper et al., 2004). Shiffman et al. (2012) reported daily smokers tend to score higher on all WISDM measures; however, when the scores are standardized, the shape of daily smoker’s profile demonstrates high scores on all primary motives (tolerance, craving, automaticity, loss of control), and ITS smokers score higher on secondary dependence motives such as positive reinforcement, taste-sensory, weight control, cue exposure, and social goads (Shiffman, Dunbar, et al., 2012). These results support research suggesting a de-emphasis on withdrawal avoidance as a motivator in ITS. Instead, smoking maintenance in ITS may be more focused on instrumental and situational cigarette use and reinforcement of behavior.

Perhaps most surprisingly, ITS and daily smokers do not differ substantially with respect to the likelihood of success when making a quit attempt (Shiffman, Tindle, et al., 2012). In fact, the majority of ITS (82%) reported failing in a recent quit attempt (with success defined as abstinence for >90 days; Tindle & Shiffman, 2011). Success rates for quitting among ITS have been estimated at 22%, which is only slightly higher than those exhibited by daily smokers (13%) (Tindle & Shiffman, 2011). Compared to daily smokers, ITS demonstrate increased variability in perceived level of addiction and ability to quit (Lenk, et al., 2009; Shiffman, Tindle, et al., 2012). In a qualitative study of college-aged daily and nondaily smokers, Berg et al. (2013) reported no difference in past year quit attempts nondaily smokers and readiness to quit in the next 30 days; however, compared to daily smokers, nondaily smokers frequently de-emphasized traditional aspects of nicotine addiction such as withdrawal, craving, and loss of control over use (Berg et al., 2013). These results highlight that, even the absence of traditional dependence criteria, ITS still exhibit difficulty maintaining sustained abstinence and
demonstrate rates of cessation failure that are similar to those associated with daily smoking (Tindle & Shiffman, 2011).

**Treatment barriers and abstinence difficulty in young adult ITS**

As a rapidly growing population of smokers, young adult ITS represent a potentially important opportunity for targeted intervention. Traditionally, studies that are focused on younger populations have utilized a model that investigates prevention and intervention efforts in adolescent smokers; however, the initiation of smoking in young adulthood is associated with similar negative health trends and nicotine addiction risk (Caldeira, et al., 2012; Halperin, et al., 2010; Wechsler, Rigotti, Gledhill-Hoyt, & Lee, 1998). Thus, while adolescent smoking remains a critical window for early prevention efforts, nondaily smoking during young adulthood offers an equally important opportunity for intervention (D. W. Brook et al., 2008; Everett et al., 1999). Compared to daily smokers, ITS are typically younger, better educated, and begin smoking at a later age (Ackerson & Viswanath, 2009; Cooper et al., 2010). Therefore, ITS in a college environment may provide a particularly useful window for intervention. Recent research has demonstrated clear separation between the self-reported smoking identities (e.g., “I think of myself as a person who smokes”) of experimental, intermittent, and daily smokers in a population of college-aged smokers (Tracy, et al., 2012). As may be expected, daily smokers had the highest smoking identity, followed by intermittent then experimental smokers. Smoking identity was positively associated with smoking rate, having a quit attempt in the previous twelve months, and interest in quitting and negatively associated with quitting self-confidence and time to first cigarette of the day (Tracy, et al., 2012). Zhu et al. (2003) reported that, in an adult sample followed over a
two year period, 13% of ITS had transitioned to daily smoking, 44.5% maintained the same smoking rate, and 36% had stopped smoking. A recent investigation in young adults echoed relatively stable ITS frequency in the first year of college with 11% increasing smoking frequency, 68% maintaining the same smoking rate, and 21% declining smoking quantities (Hoeppner, Bidwell, Colby, & Barnett, 2014). Therefore, although the majority of ITS are likely to maintain nondaily smoking behavior throughout young adulthood, even a low level of cigarette consumption still carries significant health risks. Additionally, a portion of nondaily smokers may cease or, more importantly, escalate use. Addressing maladaptive smoking patterns prior to daily use may provide avenues for early intervention. Investigation of smoking motives in a young adult ITS population may help identify smokers who are at risk for escalating to higher smoking rates and/or maintaining a pattern of nondaily smoking that still associated with difficulty with abstinence.

Despite having a similar number of quit attempts and a comparable degree of difficulty maintaining abstinence as daily smokers, ITS may not benefit from treatment models commonly used with daily smokers. Consistent with daily smokers, ITS readily acknowledge that continued consumption of cigarettes is harmful to personal health (Evans, et al., 1992) and report a similar interest in quitting (Tracy, et al., 2012). However, some research suggests that ITS may be less likely to actively seek advice on cessation (Tindle & Shiffman, 2011). Despite this potential barrier to treatment, ITS expressed a greater trust in doctors as a source of health information compared to moderate and heavy smokers (Rutten, Augustson, Doran, Moser, & Hesse, 2009). Therefore, investigation into factors associated with smoking maintenance in young
adults can provide important information for effective treatment in this understudied population.

Based on the above research, nicotine addiction and smoking maintenance in ITS do not appear to be influenced by the same factors as daily smokers. As previously described, a traditional model of dependence assumes nicotine maintenance via negative reinforcement, or “trough maintenance”, in which smokers are motivated to keep nicotine levels above a minimal level (“trough”) to avoid the experience of withdrawal symptoms (Russell, 1971). Smoking maintenance within ITS may be better categorized as “peak seekers”, or smokers who are motivated by the immediate acute, rewarding effects of nicotine (thus not having to smoke regularly) (Russell, 1971). Because addiction in ITS may be motivated by “peak seeking” as opposed to avoidance of withdrawal symptoms, individual characteristics, such as personality traits, may provide critical insight into smoking maintenance and difficulty in abstinence of ITS.

**Personality and addiction in ITS: “Peak seeking” as a motivator**

Personality traits have long been associated with nicotine dependence, increased smoking rate, and cessation outcome in addicted smokers (Cosci et al., 2009; Munafo & Black, 2007). In particular, personality traits related to disinhibition are associated with increased cigarette consumption, positive smoking expectancy, greater craving, and the initiation of smoking (Billieux, Van der Linden, & Ceschi, 2007; Paunonen & Ashton, 2001; Perkins et al., 2008). Current conceptualizations of pathological personality domains define disinhibition as an approach-related trait characterized by a tendency to behave rashly without consideration of future
consequences or potential risks (Krueger, Derringer, Markon, Watson, & Skodol, 2012). Accordingly, individuals with increased disinhibition traits frequently engage in behavior associated with rewarding stimuli (Bogg, Fukunaga, Finn, & Brown, 2012; Caspi et al., 1997; Flory & Manuck, 2009; Goudriaan, Oosterlaan, De Beurs, & Van Den Brink, 2008; Skeel, Neudecker, Pilarski, & Pytlak, 2007). Indeed, previous research has suggested that the positive outcome expectancies of alcohol mediate the relationship between trait disinhibition and increased alcohol consumption (McCarthy, Kroll, & Smith, 2001).

Similarly, approach-related reward sensitivity associated with increased disinhibition could potentially help characterize important features of addiction and smoking maintenance in “peak seeking” ITS. According to this model, a sensitivity to rewarding stimuli (e.g., the acute effects of nicotine) in ITS may be associated with smoking maintenance that could, in turn, provide a framework for targeted invention.

While personality traits are generally not explicitly addressed in the context of drug treatment, recent research has argued that consideration of relevant personality traits in addiction treatment may improve outcomes (Staiger, Kambouropoulos, & Dawe, 2007). Of primary relevance, the assessment of individual differences in trait disinhibition could be used to predict interactions between substance use driven by reward motivated behavior and situational factors or cues. Since it is hypothesized that ITS are not as motivated by the avoidance of withdrawal (i.e., “trough maintainers”), the association between personality traits and reward seeking behavior may help characterize the maintenance of smoking in ITS. Disinhibition is conceptually similar to a number of personality traits associated with addictive behavior such as impulsivity (Mitchell, 2004), risk-taking (Carton, Jouvent, & Widlocher, 1994; Cavalca et al., 2013),
and irresponsibility (J. S. Brook, Finch, Whiteman, & Brook, 2002). Unfortunately, measures associated with these constructs are subject to subtle differences in definitions (Evenden, 1999). The Personality Inventory for the DSM5 (PID5) is a recently released personality measure that includes an empirically based assessment of a number of pathological traits (Krueger, et al., 2012). This measure reflects the most updated and current research on assessment of a variety of personality traits, including disinhibition. Therefore, to evaluate motivations of ITS that are related to “peak seeking” and/or smoking maintenance, individual differences in trait disinhibition on the PID5 may provide the strongest links to problematic smoking behavior.

Although the assessment of personality facets may be useful for predicting the likelihood of smoking difficulty, such measurement does not provide detailed information regarding the mechanisms that link personality to behavior. Recent behavioral findings suggest a connection between personality facets related to disinhibition, reward processing, and problematic substance use in young adults (Dinn, Aycicegi, & Harris, 2004; Lyvers, Duff, Basch, & Edwards, 2012). For example, in a population of university students, the association between measures of impulsivity and problematic drinking behavior was mediated by a questionnaire that is designed to assess dysfunction in prefrontal and cortical brain regions implicated in reward processing and executive control (Lyvers, et al., 2012). Therefore, the differential processing of rewards may help clarify mechanisms associated with cigarette use that are related to “peak seeking”, or sensitivity to the acute, rewarding effects of nicotine (Russell, 1971).

Utilization of rewarded tasks with established relationships to neuronal regions associated with inhibitory control offers a particularly valuable tool for filling in this gap
by allowing for the investigation of potential neurocognitive processes that underlie overt disinhibition – insight that would provide a rich foundation for the development of targeted intervention strategies.

**Additional neural support for disinhibition in ITS**

Recent lines of research have demonstrated a significant relationship between biologically associated measures of disinhibition (i.e., “neurobehavioral disinhibition”) and the escalation (and desistance) of substance use in adolescents and young adults (Kirisci, Tarter, Reynolds, & Vanyukov, 2006; Tarter et al., 2003; Tarter, Kirisci, Reynolds, & Mezzich, 2004). Using fMRI, McNamee et al. (2008) found a negative association between neurobehavioral disinhibition and activation in frontal neural circuitry associated with inhibiting a response. Converging evidence from imaging studies also suggests that facets of disinhibition (e.g., impulsivity) are associated with inefficient functioning of frontal and limbic regions implicated in reward valuation (Brown, et al., 2006; Lee, Jerram, Fulwiler, & Gansler, 2011). For example, increased endorsement of disinhibition facets is related to poor use of reward-related information to guide decision-making, including initiation of smoking and binge drinking (Castellanos-Ryan, Rubia, & Conrod, 2011; Perkins, et al., 2008; Sweitzer, Donny, & Hariri, 2012). Taken together, behavioral and brain imaging research characterizing the connections between pathological disinhibition, reward processing, and substance use provide key data regarding potential neurocognitive mechanisms that may contribute to problematic smoking trajectories of ITS during young adulthood. Specifically, increased disinhibition may relate to a sensitivity to rewards that results in poor decision-making and maintenance of smoking behavior via “peak seeking” in ITS.
Central to investigating the association between disinhibition and reward activation in nondaily smokers is the functional integrity of reward-related brain regions in addicted populations. Aberrant processing of reward-related information is a core feature of drug addiction (Everitt & Robbins, 2005; Koob & Volkow, 2010). Substance-dependent individuals demonstrate dysfunctional reward processing and exhibit behavioral characteristics associated with poor goal-directed behavior (Goldstein, Alia-Klein, et al., 2007; Martin-Soelch et al., 2001). Based on a traditional model of dependence in daily smokers, addicted individuals exhibit an insensitivity to nondrug rewards that is proportionate to their level of self-control, compared to demographically matched healthy controls (Goldstein, Alia-Klein, et al., 2007). Further, research suggests that there may be a direct link between the motivational biases displayed by smokers and the functioning of the striatum (Buhler et al., 2010; Das, Cherbuin, Anstey, Sachdev, & Easteal, 2011; Luo, Ainslie, Giragosian, & Monterosso, 2011; Peters et al., 2011; Wilson, Sayette, Delgado, & Fiez, 2008). The striatum is known to be central to the valuation and processing of rewards (Delgado, 2007). Several lines of evidence indicate that the magnitude of the striatal response to rewards is sensitive to the subjective valuation of such stimuli (Delgado, 2007; Nieuwenhuis et al., 2005; Pine et al., 2009). More specifically, dependent smokers demonstrate reduced activation in the striatum in response to monetary gains when expecting an opportunity to smoke (Wilson, et al., 2008). Therefore, the degree to which addicted individuals are motivated by nondrug rewards may provide an index of the value associated with the stimuli and, by extension, the influence that the stimuli are likely to have over the behavior of the individual.
Very few studies have directly addressed reward responsiveness in low-level or nondaily smokers. When investigating varying levels of daily smokers, findings suggest that light daily smokers may demonstrate reward-processing biases similar to those exhibited by heavier daily smokers (Fields, Collins, Leraas, & Reynolds, 2009; Johnson, Bickel, & Baker, 2007; Reynolds, 2004). While empirical investigation of ITS is relatively new, a few studies suggest nondaily smokers may process rewards differently compared to daily smokers. Buhler and colleagues (2010) evaluated brain activation associated with both cigarette and nondrug rewards in daily and nondaily smokers. The results indicated that daily, compared to nondaily, smokers demonstrated reduced brain activation in mesocorticolimbic regions (e.g., caudate, striatum, orbital frontal gyrus, etc.) in response to both drug (cigarette) and nondrug (money) rewards (Buhler, et al., 2010). The authors speculated that increased reward response among nondaily smokers might serve as a “protective” mechanism in nondaily smoking by reducing the liability of dependence (Buhler, et al., 2010). However, based on the previously summarized evidence of smoking maintenance in ITS, increased motivation for rewarding stimuli may actually predispose ITS for continued smoking behavior. Therefore, ITS with higher pathological disinhibition, relative to low disinhibition, may demonstrate improved performance when a behavior is rewarded. Contrary to findings from daily smokers, the reward motivated improvement may not be a protective mechanism but actually maintain nondaily smoking behavior via sensitivity to rewarding stimuli.

**Reward motivation and inhibitory control: Linking disinhibition to smoking maintenance in ITS**
Rewards have an impact on a host of psychological processes (Bjork, Smith, & Hommer, 2008; Delgado, 2007; Delgado, Li, Schiller, & Phelps, 2008). Particularly relevant to smoking maintenance in ITS, a hypersensitivity to rewarding stimuli can impact the extent to which they motivate the ability to exert cognitive control over behavior. Several studies have shown that rewards enhance performance on tasks that require the inhibition of prepotent responses in non-clinical samples (e.g. Geier, Terwilliger, Teslovich, Velanova, & Luna, 2010; Kalivas & Volkow, 2005; Savine & Braver, 2010). Recent brain imaging research suggests that the performance-enhancing effects of incentives are linked to incentive-related modulation of activation in areas of the brain supporting reward processing (Beck, Locke, Savine, Jimura, & Braver, 2010; Geier, et al., 2010; Savine & Braver, 2010). In particular, behavioral tasks that include rewarded response inhibition offer an opportunity to investigate the degree to which rewards influence individual behavior.

Saccadic eye movement tasks provide valuable insight into cognitive processes of both healthy individuals and psychiatric populations (for review see: Hutton, 2008; Gooding & Basso, 2008). Antisaccades, in which participants attempt to resist a prepotent urge to look in the direction of a peripheral stimulus, are a precise assessment of top-down cognitive control processes related to response inhibition. Common metrics for saccade tasks include the saccade latency (e.g., duration from stimulus presentation to saccade), accuracy of saccade, and peak velocity of eye movement (Hutton, McCaul, Santora, & Erbelding, 2008). By incentivizing the behavior on the antisaccade task, researchers can investigate the motivational influence of monetary reward on task behavior (Geier, et al., 2010). Previous research has
demonstrated fewer inhibitory errors and shorter saccade latencies on rewarded versus nonreward antisaccade trials (Blaukopf & DiGirolamo, 2006; Geier & Luna, 2012; Hardin, Schroth, Pine, & Ernst, 2007; Jazbec et al., 2006).

A major advantage of the rewarded antisaccade task over other response inhibition tasks lies in the extensive research characterizing neural network responsible for saccade preparation and execution (for review see: McDowell, Dyckman, Austin, & Clementz, 2008). For example, recent data suggest that reward-related influences on the performance of an antisaccade task are associated with activation of the striatum (Beck, et al., 2010) – a brain region that may be a sensitive marker for increased reward sensitivity related to “peak seeking” smoking maintenance in ITS. Furthermore, Harsay et al. (2011) demonstrated increased functional connectivity between the ventral and dorsal striatum and cortical oculomotor structures predicted individual differences in behavioral benefit of rewards during a rewarded antisaccade task. This study provides direct evidence that neural connectivity of reward and control-related brain regions during rewarded saccade trials are associated with individual motivation to earn an incentive (Harsay et al., 2011).

The ability to inhibit a prepotent response to achieve a desired reward is a useful analogue to resisting the desire to use (thus achieving good health) during a quit attempt. Daily cigarette smoking is positively associated with impaired inhibitory control on antisaccade tasks (Spinella, 2002) and, compared to nonsmokers, reduced striatal activation during rewarded antisaccade trials (Geier, Sweitzer, Denlinger, Sparacino, & Donny, 2014). Importantly, these performance deficits are frequently attributed with the experience of withdrawal and are posited to represent a potential mechanism of relapse
(Geier, et al., 2014; Powell, Dawkins, & Davis, 2002). Furthermore, withdrawal-related antisaccade performance deficits are exacerbated in those with high impulsivity traits (Pettiford et al., 2007). Billieux et al. (2010) reported individuals who smoke less than 10 cigarettes per day have better response inhibition capacities than those who smoked 11-20 cigarettes per day. Additionally, decreased response inhibitory capacity predicted increased scores on Fagerstrom Test for Nicotine Dependence, a measure that emphasizes smoking to avoid withdrawal symptoms (Billieux et al., 2010).

Based on these findings, one might assume that smokers higher in trait disinhibition would demonstrate decreased performance on rewarded antisaccade trials that may relate to the resumption of smoking behavior and alleviation of withdrawal symptoms. Given nondaily smokers are likely not motivated by the experience of withdrawal, it is possible that “peak seeking” ITS who are high in trait disinhibition may actually be more motivated by rewarding stimuli and thus demonstrate increased performance on rewarded (relative to nonrewarded) antisaccade trials. Thus, nondaily smokers who have an increased propensity to engage in detrimental behaviors without consideration of risk may be more inclined to smoke cigarettes and this relationship may be facilitated by “peak seeking” characterized by an increased motivation for rewarding stimuli.

To our knowledge, reward-motivated response inhibition has not been examined as a possible mechanism relating facets of disinhibition and maintenance of smoking behavior in ITS. Two lines of evidence offer support for the notion that traditional conceptualizations of addiction are related to the degree to which reward incentives enhance cognitive control performance. In the current proposal, nondaily smokers are
hypothesized not to fit the traditional model of dependence that emphasizes the experience of withdrawal; however, ITS are expected to be strongly influenced by nondrug rewards. One line of evidence comes from recent research documenting a positive association between individual differences in reward sensitivity and reward-contingent cognitive control in non-clinical young adults (Locke & Braver, 2008). That is, rewarding stimuli are associated with increased activation in prefrontal regions during a task requiring effortful control. This idea would be consistent with the hypothesis that young adult ITS who are motivated by nondrug rewards will exhibit performance improvements on incentivized task trials. A second line of evidence comes from research examining reward responsiveness and neurocognitive functioning in cocaine addiction (Goldstein, Alia-Klein, et al., 2007; Goldstein, Tomasi, et al., 2007). These studies have found that, among cocaine users, sensitivity to rewards was positively associated with reward-related activation of the prefrontal cortex (Goldstein, Tomasi, et al., 2007), and prefrontal reward activation was also significantly related to increased trait self-control (i.e., low disinhibition; Goldstein, Alia-Klein, et al., 2007). Taken together, these results suggest that activation of reward-related regions in substance users is associated with activation of control-related brain regions that are related to individual differences in personality.

Smoking maintenance in ITS is hypothesized to be motivated by “peak seeking”, or a sensitivity to rewarding stimuli. Increased disinhibition in young adult ITS is likely to be associated with increased motivation for rewarding stimuli. As such, saccade responses on incentivized trails may represent a potential mechanism linking disinhibition to problematic smoking behavior in young adult ITS (Figure 1). Specifically,
it is hypothesized that reward-motivated response inhibition will mediate the relationship between pathological disinhibition and momentary factors associated with reward seeking behavior/subjective effects of nicotine. In other words, as disinhibition \((X)\) increases, reward seeking behavior/subjective effects of nicotine \((Y)\) will also increase, and elevated reward motivation \((M)\) will mediate this path.

**Summary and significance**

The current study is an initial step to investigating a potential neurocognitively-based mechanism associated with disinhibition and maintenance of smoking behavior in ITS, a rapidly growing but understudied population. By comparing reward motivated response inhibition to factors associated with the act of smoking as well as reward seeking behavior during a subsequent EMA data collection period, I intend to elucidate the link between reward-motivated behavior of ITS and momentary functioning in a naturalistic environment. Results from this work would have several significant implications. **Clinically**, there is an acute need to develop a better understanding of the factors that contribute to nondaily smoking, as ITS pose a substantial public health burden. **Conceptually**, understanding individual differences in the mechanism by which disinhibition influences problematic smoking behavior in ITS will provide targets that may be amenable for immediate intervention (e.g., rewards that can be increased or decreased) and evaluate the potential value of including interventions addressing pathological personality traits that contribute to nicotine addiction.
Figure 1: Model depicting hypothesized relationship between disinhibition and reward seeking/nicotine effects mediated by reward contingent inhibitory control
MATERIALS AND METHODS

Participants

Fifty young adults ranging in age from 18-25 years (M=20.75, SD=1.7, 51% male) were recruited from the Penn State student population and from the surrounding community via media advertisements. Among these participants, 77% were Caucasian, 10% Hispanic, 10% African-American, and 4% Asian. Eligible participants identified as a smoker, reported smoking on “some (but not all) days” and reported a lifetime cigarette count exceeding 100. These criteria have recently been used to distinguish ITS from daily and experimental smokers in a college-aged population (Tracy, et al., 2012). Exclusionary criteria included regular use of any drug other than nicotine, current diagnosis of any psychological disorder, the endorsement of active efforts to try to quit smoking, reported cardiovascular disease (such as heart disease, heart attack, stroke, or angina) or respiratory disease (such as asthma, chronic bronchitis, or chronic obstructive pulmonary disease) during the past year, and reported smoking on "some days" but having smoked less than 100 lifetime cigarettes. The local Institutional Review Board approved the study and written informed consent was obtained from all participants.

Summary of approach

Participants were asked to smoke normally prior to the experiment session. After informed consent was obtained, participants provided an expired air carbon monoxide (CO) reading, which involved holding their breath for 15 sec and then exhaling into a hand-held monitor, and a salivary sample to test for the presence of cotinine in order to
confirm their smoking status (CO reading was required to be > 4 parts per million or salivary cotinine reading greater than 10 ng/ml to be eligible to complete the study). Eligible participants then completed a rewarded antisaccade task and standard battery of questionnaires that included a variety of measures to assess nicotine addiction, smoking behavior, and personality (listed below). The day after the experiment session, participants began an EMA data collection period during which they completed event-contingent (e.g., after smoking a cigarette), interval-contingent, and signal-contingent surveys on a lab provided smartphone over a period of 7 days.

**Questionnaires**

Participants completed a battery of questionnaires that assessed smoking behavior, nicotine addiction, and personality. In addition to a standard demographics questionnaire, participants completed a standard smoking and substance use demographic questionnaire, NDSS (Shiffman, et al., 2004), Smoking Identity scale (SI; Tracy, et al., 2012), Wisconsin Predicting Patients’ Relapse questionnaire (WI-PREPARE; Bolt et al., 2009), WISDM (Piper, et al., 2004), Addiction Stage Assessment (ASA; J. DiFranza et al., 2010), the Questionnaire of Smoking Urges – Brief (QSU-B; Cox, Tiffany, & Christen, 2001), the Center for Epidemiological Studies – Depression scale (CES-D; Radloff, 1977), Reward Responsiveness scale (Van den Berg, Franken, & Muris, 2010), the Personality Inventory for DSM-5 (PID5; Krueger, et al., 2012), UPPS-P Impulsivity Scale (Whiteside & Lynam, 2001), Pathological Narcissism Inventory (PNI; Pincus et al., 2009), Inventory of Interpersonal Problems Circumplex Scales (IIP-C; Alden, Wiggins, & Pincus, 1990), and the Balanced Inventory of Desired Responses (BIDR; Paulhus, 1991). For the current study, smoking demographics were
obtained from the smoking history questionnaire and responses from the Smoking Identity questionnaire and the PID5 were included in the subsequent analysis (described below). All other measures were not the focus of the primary hypotheses and are not described further or included in dissertation analysis.

**Smoking Identity scale**

The SI scale is a 9-item measure specifically designed to capture smoking identity in a college-aged population with a wide range of smoking patterns. Items relate to college student’s perceptions of what it means to be a smoker. Participants responded to statements using a 6-point Likert scale ranging from “Strongly disagree” to “Strongly agree”. Overall smoking identity has previously been used to differentiate between daily, nondaily, and experimental young adult smokers (Tracy, et al., 2012). Reliability of the SI for this study was high with a Chronbach’s alpha equal to .97.

**Personality Inventory for DSM-5**

The PID5 is a 220-item questionnaire assessing the presence of a variety of pathological personality traits. The measure consists of 25 primary scales that load onto five higher order dimensions (i.e., Negative Affect, Detachment, Antagonism, Disinhibition, and Psychoticism). Item responses to statements use a 4-point scale (0, Very false or often false; 1, Sometimes or somewhat false; 2, Sometimes or somewhat true; 3, Very true or often true). Overall reliability of the PID5 for this study was high with a Chronbach’s alpha equal to .95. Since the focus of the current study is to investigate disinhibition facets associated with a potential sensitivity to rewards, the following disinhibition facets were averaged to calculate a total disinhibition score: risk-taking,
impulsivity, and irresponsibility. This approach is consistent with previous research highlighting alternative hierarchical structures within PID5 facets (Wright et al., 2012).

**Rewarded Antisaccade Task**

The antisaccade task is a measure of response inhibition that asks participants to look towards (i.e., prosaccade) or away (i.e., antisaccade) from a peripheral stimulus (a yellow dot). The rewarded antisaccade task in the current study was adapted from prior research (Geier, et al., 2010) and included viewing one of three “cue” images (2000ms) at the start of each trial (Figure 2). The cue image was comprised of a central fixation cross (1.5 degrees/visual angle), the color of which indicated whether the participant should prepare to look towards or away from the peripheral stimulus, surrounded by a ring of symbols that indicated the trial type. If the central fixation cross was green, participants were instructed they should prepare to look towards the peripheral stimulus when it appears. If the central fixation cross was red, the participants were instructed that they should prepare to inhibit a response by looking away (i.e., look in the mirror location) from the peripheral stimulus when it appears. The three trial types were: 1) a ring of green dollar signs ($), indicating that the forthcoming trial was monetarily rewarded if performed correctly, 2) a ring of blue pound signs (#) indicating that no money is at stake on that trial, or 3) a ring of red x’s (X) indicating that the trial money was lost if performed incorrectly. Next, a peripheral target appeared at one of four unpredictable locations on the horizontal meridian, either to the left or right (plus or minus 4 or 8 degrees). To reduce the predictability of peripheral target presentation, the time between cue presentation and peripheral stimulus was randomly jittered by 250ms and 400ms. During this epoch, participants were given immediate, auditory
performance feedback ("correct" or "incorrect", 400ms tones) using interfaced stimulus presentation and eye tracking software. A white fixation cross was presented between individual trials (2000ms). In sum, 12 complete reward trials, 12 complete neutral trials, and 12 complete loss trials were presented in each run, with 6 prosaccade and 6 antisaccade trials within each trial type. Four runs were presented per session for a total of 48 complete reward trials, 48 complete neutral trials, and 48 complete loss trials. Participants were informed that they would earn up to an additional $10 (paid in cash at the end of the experiment session) based on their performance on the rewarded antisaccade task. A computer program kept track of the monetary outcomes for each participant as they are performing the rewarded-antisaccade task.

**Eye Tracking**

Eye movements were obtained using ASL (Applied Science Laboratories, Bedford, MA) eye tracking system that recorded eye position by a pupil-corneal reflection with a resolution of 0.5 degree of visual angle. At the beginning of the antisaccade task, and between runs where necessary, a 9-point calibration procedure was performed. Stimuli were presented using E-Prime (Psychology Software Tools, Inc. Pittsburgh, PA) and were displayed on a computer monitor position approximately 18 inches from the participant’s eye. Eye data were scored off-line using ILAB software (Gitelman, 2002) and an in-house scoring suite written in MATLAB (Mathworks, Inc.). To investigate the influence of rewards on inhibiting behavior, the following analysis is focused on saccade responses during reward, loss, and neutral antisaccade trials. A correct response on an antisaccade trial was one in which the first eye movement during the saccade response epoch (after peripheral target presentation) with a velocity
greater than 30°/s (Gitelman, 2002) was made toward the mirror location of the peripheral cue and extended beyond a 2.5°/visual angle central fixation zone. Antisaccade errors occurred when the first saccade during the saccade response epoch was directed toward the peripheral stimulus and exceeded the 2.5°/visual angle central fixation zone. Trials in which no eye movements were generated were excluded from further analysis. Data from two participants included significant noise that resulted in unreliable velocity and latency parameters; for these participants, only saccade accuracy (obtained by visual inspection of saccade data and cross-checked with E-Prime accuracy data) was utilized for analysis.

7-day EMA data collection period

After completing questionnaires, participants received training on how to use a lab provided smartphone (Motorola DROID X2, Verizon) to respond to surveys over the subsequent 7-days. During this time, participants were asked to complete an interval contingent, event-contingent, and signal-contingent measure on the lab provided smartphone (see Appendix A for individual survey items). Participants were asked to complete a morning survey (interval-contingent) within 60 minutes of waking up. Results from the morning survey were not used in the present analysis. Participants were also asked to complete a smoking survey (event-contingent) immediately after smoking any portion of a cigarette. Signal-contingent surveys (i.e., “beeped” surveys) were designed to capture data within a “slice of time” in the participant’s naturalistic environment. For the current study, beeped surveys were used to represent nonsmoking occasions within the individual’s natural environment. Beeped survey notifications occurred four times a day between the hours of 9am and 9pm using a pseudo randomized schedule fixed
across participants (i.e., 28 possible samples over 7 days). The signals were randomized to occur within once within a three hour time block distributed evenly throughout the day. Importantly, the beeped surveys included the much of the same information as the smoking survey. The repetition of specific survey items allows for comparison between individual patterns of responses throughout the day with responses under the influence of nicotine immediately after smoking a cigarette. The smoking and beeped survey each contained items that assessed momentary socio-emotional and situational factors (including presence of others, craving, emotional states, etc.). Survey questions used in the current analysis relate to sensation seeking behavior and the subjective effects of nicotine. The propensity for sensation seeking on both smoking and beeped surveys was assessed by a 100 touch point continuum question: “How adventurous do you feel right now?”. During the smartphone training, participants were instructed to respond to this question by indicating “how likely it would be that [they] would do something [they] normally wouldn’t do”. Subjective effects of nicotine were measured by two 100 touch point continuum items were presented only during the smoking survey: “During your last cigarette, rate how much you felt dizzy” and “During your last cigarette, rate how much you felt a rush or buzzed”. Similar measures of nicotine reactivity have previously been reported as important predictors of relapse (Strong et al., 2011) and momentary motivators of smoking behavior (Piasecki, Richardson, & Smith, 2007).

Both the signal and event contingent measures also included a cognitive task that evaluated momentary reward sensitivity in the participant’s natural environment. Specifically, participants performed a modified version of the Balloon Analogue Risk
Task (BART; Lejuez et al., 2002). The BART is a well-validated laboratory based choice task in which participants decide how much to inflate a simulated balloon presented on a computer screen before it bursts and has been previously correlated with risk-taking behavior and reward sensitivity (Lejuez, Aklin, Zvolensky, & Pedulla, 2003; Pleskac, Wallsten, Wang, & Lejuez, 2008). Performance on the BART has been shown to predict risk-taking behaviors after controlling for personality traits (Skeel, et al., 2007), thus demonstrating unique information beyond characterological report of disinhibition traits. Additionally, decreased activation in the medial prefrontal cortex, a region associated with cognitive control, during reward seeking behaviors (successive inflation choices) on the BART has been associated with increased alcohol consumption and greater trait disinhibition (Bogg, et al., 2012).

The current study employed a novel momentary version of the BART (mBART). The mBART application would open automatically after the final question on the smoking and beeped surveys. The mBART utilized many of the same features as the traditional behavioral BART. Specifically, participants earned 5 cents for each successful pump, which is the most common reward value used for BART administrations. The mBART also used the most common break-point for balloon explosions (64 out of a 128 pumps). The traditional BART commonly uses 30 balloons per administration; however, in order to adapt the mBART for the momentary assessment, participants completed 15 balloons per task administration. The selection of 15 balloons per mBART trial was based on data suggesting that the relative degree of riskiness on the traditional 30 balloon BART was stable after the first 10 balloons (Lejuez, et al., 2002). Participants “pumped” balloons by holding down a button on the
touch screen of the phone (Figure 3). The participant could “bank” money on a balloon by pressing the “Collect$$” button on the screen. The money from that balloon would be added to a total amount earned for the trial and the next balloon would appear. If, however, the balloon “popped” prior to the participant banking the points, the participant lost the money earned on that balloon and the next balloon would appear. Increased risk-taking (i.e., reward seeking) on a given mBART trial was measured by the average number of pumps on unpopped balloons (i.e., adjusted average pumps) and increased number of “popped” balloons. These two variables have previously been used to assess the degree of risk taking using the traditionally administrated BART (Lejuez et al. 2002; Skeel, et al., 2007; Ryan, Mackillop, & Carpenter, 2013).

Three participants completed less than 50% of the beeped surveys and one participant who did not complete any smoking surveys over the 7-day EMA data collection period were excluded from subsequent analysis. Therefore, the final sample for analysis was forty-six young adult ITS. All participants completed the full 7 days resulting in 322 total person-days during which 979 beeped surveys (mean response rate = 76%) and 259 smoking surveys for study analysis.

**Statistical Analyses**

The first step of analysis was focused on the identifying saccade variables associated with the motivational role of incentives on performance. To investigate differences in peak saccade velocity, saccade latency, and saccade accuracy between the three rewarded antisaccade trial types (i.e., reward, loss, and neutral), separate repeated measure analysis of variance (ANOVA; IBM SPSS Statistics v.21) were
performed for each saccade performance variable. Post-hoc tests were used to identify performance on reward and loss saccade variables (i.e., chance to earn or avoid losing a reward) that were significantly different from neutral (i.e., no reward). Significantly different saccade variables were used as an indicator of reward motivation in the subsequent analysis. The comparison of reinforcement trials (i.e., reward and loss) to neutral trials has been used in previous research to investigate the motivational aspect of incentives in clinical populations. Several studies have reported no significant differences in reward and loss antisaccade trials in healthy subjects (Blaukopf & DiGirolamo, 2006) and participants diagnosed with depression or anxiety (Jazbec, McClure, Hardin, Pine, & Ernst, 2005). Furthermore, Jazbec et al. (2005) reported higher antisaccade accuracy on combined reward and loss trials compared no incentive (i.e., neutral) trials. To reduce the possibility of Type I errors, post-hoc tests were Bonferroni corrected for multiple comparisons.

The primary analysis examined reward motivated inhibitory control as a potential mediator between pathological disinhibition and two momentary outcomes: reward seeking and subjective nicotine effects. Four planned path models were used to calculate both the direct and indirect effects of disinhibition through reward motivation on momentary outcomes. Path analysis was conducted in MPlus v7.2 (Methuen & Methuen, 2012).

The increasing use of EMA data collection, especially in addiction research where context and emotion are thought to play a vital role in maintenance of drug use, has resulted in evolving data analysis techniques (for review see: Shiffman, 2013). The primary hypothesis guiding the current research project is that young adult ITS exhibit
different behavioral patterns while smoking compared to not smoking and that the rewarding effects of nicotine are potentially relevant to smoking maintenance. As such, EMA measurements were collapsed into two different times: responses from smoking and beeped (i.e., nonsmoking) surveys. Including responses from both time points in the same mediational model permits the investigation of the specific indirect effects of pathological disinhibition and reward motivation on smoking survey responses conditional on the inclusion of the corresponding beeped survey responses. In order to measure multiple indirect effects, mediational paths were estimated using bias corrected 95% bootstrap (5000 iterations) confidence intervals (Preacher & Hayes, 2008). This approach has considerable advantages over alternative mediation analysis techniques including no assumption of multivariate normality and a greater power to detect effects (Preacher & Hayes, 2008). Three mediational models investigating reward seeking tested the specific indirect effect of reward motivation (M) to mediate the effect of pathological disinhibition (X) on outcome variables in beeped (Y₁) and smoking (Y₂) surveys. Outcome variables included previously identified variables from beeped and smoking surveys: average adjusted pumps on mBART, number of popped balloons on mBART, and self-reported adventurousness. A fourth model exploring subjective effects of nicotine tested the specific indirect effect of reward motivation (M) to mediate the effect of pathological disinhibition (X) on outcome variables of dizzy (Y₁) and rush (Y₂) taken only from smoking surveys.
Figure 2: Schematic of rewarded antisaccade task

Cue: loss, reward, neutral
2000ms

Saccade response (200ms; jittered by 250ms or 400ms)

Inter-trial interval (2000ms)
Figure 3: Depiction of participant interface for mobile balloon analogue risk task
RESULTS

Characteristics of nondaily smokers

Consistent with emerging literature on nondaily smokers, study participants demonstrated considerable variability in smoking characteristics. Participants reported smoking an average of 12.41 (SD = 5.1) days in the past 30 days with a range spanning 3 to 25 days. On smoking days, participants reported smoking an average of 2.79 (SD = 1.4) cigarettes with a range of 1 to 7 cigarettes. Expired CO ($M = 3.29$ppm, SD = 4.9, range = 1 to 30) and salivary cotinine (range = 10 to 500ng/mL) also demonstrated considerable heterogeneity. The total score on the SID ($M = 22.86$, SD = 4.6) was consistent with reported SID results from Tracy et al. (2012) that distinguished daily, nondaily, and experimental smokers (average SID score of 38.5, 21.9, and 17.8, respectively). Over the 7-day EMA data collection period, participants reported smoking an average of 5.67 (3.3) cigarettes on smoking days with 4 as the modal number of cigarettes smoked.

Eye tracking results

As expected, paired t-tests between performance on prosaccade and antisaccade (AS) trials (averaged across trial types) demonstrated AS trials were associated with higher latency (309.33ms versus 242.1ms, $t(48) = 7.38$, $p < .001$), higher velocity (146.7deg/s versus 125.9deg/s, $t(48) = 3.06$, $p < .01$), and lower accuracy (87.8% versus 95.5%, $t(48) = -4.25$, $p < .001$). Repeated measures ANOVAs were performed to evaluate performance differences on reward, loss, and neutral AS trials. Only correct saccade responses were utilized for latency and velocity analyses. The first repeated measures ANOVA evaluated differences in saccade latency between reward (mean = 312.3ms), loss (mean = 316.7ms), and neutral (mean = 301.1ms) AS
trials. Results revealed no significant main effect of latency \[ F(1,43) = .74, p = .40 \]; therefore, the time between presentation of a peripheral stimulus and when the participant initiated a saccade in the opposite direction were statistically equivalent across trial types. The second repeated measures ANOVA evaluated differences in saccade velocity between reward (mean = 142.7°/s), loss (mean = 145.6°/s), and neutral (mean = 146.6°/s) AS trials. There was not a significant main effect of peak velocity \[ F(1,43) = .80, p = .38 \], indicating no differences in saccade velocity across trial types. The final repeated measures ANOVA evaluated differences in saccade accuracy between reward (mean = 88.5%), loss (mean = 90.7%), and neutral (mean = 82.4%) trials. The percentage of correct AS was calculated for each trial type. Results demonstrated a significant main effect of trial type \[ F(1,45) = 25.64, p < .0001, d = .48 \]. Bonferroni corrected post-hoc analysis of the estimated marginal means revealed accuracy on both reward and loss trials were significantly greater than accuracy on neutral \( p’s < .0001 \). Consistent with previous research, accuracy on reward and loss trials was not significantly different \( p = .17 \). Since performance on both reward and loss trials involve performing a behavior to earn or avoid losing a reward, and error rates on both reward and loss trials were significantly different from neutral trials, individual error rates on reward and loss trials were averaged to create one variable representing reward motivation. As described above, combining reward and loss antisaccade trials has previously been used to represent incentive motivation in healthy and clinical populations (Blaukopf & DiGirolamo, 2006; Jazbec, et al., 2005).
Mediation models

As previously mentioned, four a priori meditational models were performed. Each of the models tested the hypothesis that “peak seeking” nondaily smokers are sensitive to rewarding stimuli that may maintain smoking behavior. Using data from both smoking and beeped surveys, the first three models tested the hypothesis that reward motivated response inhibition mediates the relationship between disinhibition and reward seeking behavior. A final model used data from only the smoking survey to test the hypothesis that reward motivated response inhibition mediates the relationship between disinhibition and self-reported subjective effects of nicotine immediately after smoking a cigarette. Zero order correlations between mediation variables are presented in Table 1. Notably, the high correlation between some variables on momentary surveys (e.g., adjusted average pumps and balloons popped within a survey) suggests that there was significant overlap between the two variables. However, to keep with the a priori study hypotheses, models with each study variable were still performed to evaluate potential momentary differences between event and signal contingent surveys.

Reward seeking

The first two meditational models utilized mBART data from both the beeped (i.e., nonsmoking) and smoking mBART administration. In the first model, number of target pumps on smoking ($Y_1$) and beeped ($Y_2$) surveys was predicted by disinhibition ($X$) with reward motivation ($M$) was the potential mediator (Figure 4). Only the direct effect from reward motivation to target average pumps on beeped surveys was found to be marginally significant ($\beta = .37, p = .07$). These results suggest that greater reward motivation (operationalized as increased performance on incentivized AS trials) was
associated with greater momentary reward seeking behavior on the mBART on non-smoking occasions, but not after smoking a cigarette ($p = .12$). Disinhibition was not related to reward seeking behavior after smoking a cigarette ($p$’s > .85) or reward motivation ($p = .13$). The indirect effect of disinhibition on adjusted total pumps through reward motivation was not significant for beeped ($\beta = -.05, p = .24, 95\% CI = -.13 - .02$) or smoking ($\beta = -.04, p = .26, 95\% CI = -.11 - .02$) surveys.

In the second model, number popped balloons on smoking ($Y_1$) and beeped ($Y_2$) surveys was predicted by disinhibition ($X$) with reward motivation ($M$) was the potential mediator (Figure 5). Similar to target average pumps, only the direct effect from reward motivation to number of popped balloons on beeped surveys was found to be significant ($\beta = .42, p = .03$). Consistent with the first model, greater reward motivation was associated with a greater number of popped balloons on the mBART on nonsmoking occasions, but not after smoking a cigarette ($p = .24$). Disinhibition was not related to reward seeking behavior on smoking or nonsmoking surveys ($p$’s > .59) or reward motivation ($p = .13$). The indirect effect of disinhibition on number of popped balloons through reward motivation was not significant for beeped ($\beta = -.06, p = .21, 95\% CI = -.39 - .01$) or smoking ($\beta = -.04, p = .33, 95\% CI = -.39 - .01$) surveys. Although hypothesized mediation pathways were not significant, the highlighted relationships direct paths between reward motivation and reward seeking on the mBART provide promising support for the momentary assessment of risk-taking using a novel mobile application.

In the third model, self-reported adventurousness on smoking ($Y_1$) and beeped ($Y_2$) surveys was predicted by disinhibition ($X$) with reward motivation ($M$) was the
potential mediator (Figure 6). Direct paths from disinhibition (β = 0.37, p = 0.02) and reward motivation (β = 0.34, p = 0.01) to self-reported adventurousness after smoking a cigarette were significant; however, direct paths from disinhibition and reward motivation to self-reported adventurousness during nonsmoking surveys were not (p's > 0.27). Disinhibition was not related reward motivation (p = 0.13). The indirect effect of disinhibition on adventurousness through reward motivation was not significant for beeped (β = -0.14, p = 0.76, 95% CI = -3.31 – 0.95) or smoking (β = -0.05, p = 0.27, 95% CI = -5.29 – -0.11) surveys. These results suggest that, relative to nondaily smokers with low disinhibition, more disinhibited ITS experience higher levels of adventurousness after smoking a cigarette, accounting for adventurousness when not smoking a cigarette. Additionally, nondaily smokers who demonstrate increased motivation for nondrug rewards, compared to those whose behavior was not as motivated by incentives, also experience higher levels of adventurousness after smoking a cigarette, accounting for adventurousness when not smoking a cigarette. While the hypothesized indirect paths were not significant, increased disinhibition and reward motivation appear to uniquely predict increased of adventurousness immediately after smoking a cigarette. 

Subjective nicotine effects

In the fourth model, subjective reports of “dizzy” (Y₁) and “rush” (Y₂) immediately after smoking a cigarette was predicted by disinhibition (X) with reward motivation (M) was the potential mediator (Figure 7). The direct path from disinhibition to “dizzy” was significant (β = 0.36, p = 0.03), but not from disinhibition to “rush” (p = 0.83). Direct paths from reward motivation to “rush” and “dizzy” were not significant (p’s > 0.91). Disinhibition was not related reward motivation (p = 0.13). The indirect effect of disinhibition on
subjective nicotine effect through reward motivation was not significant for dizzy ($\beta = .004$, $p = .93$, 95% CI = -1.22 – 1.84) or rush ($\beta = .00$, $p = .99$, 95% CI = -2.16 – 1.45). The significant direct path from disinhibition to subjective dizziness after smoking a cigarette suggests that ITS who are higher on pathological disinhibition may experience increased feelings of euphoria immediately after smoking a cigarette compared to those who are less disinhibited. Similarly, experiencing a rush sensation may not be a motivating factor for continued use.
Table 1: Correlations between variable used in four meditational models

<table>
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<tr>
<th></th>
<th>Disinhibition</th>
<th>Reward Motivation</th>
<th>Smoke Survey</th>
<th>Beeped Survey</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reward Motivation</td>
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<td>-</td>
<td></td>
<td></td>
</tr>
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<td>Adventurous</td>
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<td>0.324*</td>
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<td></td>
</tr>
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<td>-0.08</td>
<td>0.26</td>
<td>-</td>
</tr>
<tr>
<td>Rush</td>
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<td>0.01</td>
<td>-0.09</td>
<td>.475**</td>
</tr>
<tr>
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<td>-0.18</td>
<td>-0.06</td>
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<tr>
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<td>.634**</td>
<td>0.14</td>
</tr>
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<td>.368*</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>Popped Balloons</td>
<td>-0.09</td>
<td>.425**</td>
<td>0.12</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

* = p < .05, ** = p < .01
Figure 4: Results from meditational model investigating adjusted average pumps on the mobile balloon analogue risk task

Significant direct paths are in **bold**: $\S = p < .08$
Figure 5: Results from meditational model investigating number of popped balloons on the mobile balloon analogue risk task

Significant direct paths are in **bold**: * = $p < .05$
Figure 6: Results from meditational model investigating self-reported adventurousness on smoking and beeped surveys

Significant direct paths are in **bold**; * = *p* < .05
Figure 7: Results from meditational model investigating subjective effects of nicotine on smoking surveys

Significant direct paths are in **bold**; * = p < .05
DISCUSSION

The primary hypothesis that reward motivated response inhibition mediates the relationship between disinhibition and momentary factors associated with reward seeking behavior/subjective effects of nicotine was not supported in any of the four path models. However, the results do demonstrate potentially relevant relationships between personality and reward-related behavior in ITS that can be applied to begin to understand motives in a growing population of young adults who smoke on a nondaily basis.

The current study results reveal associations between disinhibition, reward motivation, and momentary behavior in young adult ITS that provide preliminary evidence for potential motivators of smoking behavior. Nondaily smokers are a growing population that exhibit similar rates of cessation failure and quit attempts as daily smokers (Tindle & Shiffman, 2011). Since nondaily smokers do not intake nicotine at regular intervals, traditional models of addiction and treatment that emphasize withdrawal avoidance likely do not capture motivators for smoking behavior in this population. One possibility is that young adult ITS are motivated by “peak seeking”, or maintaining smoking behavior due to the immediate rewarding effects of nicotine. Thus, individuals who are higher in personality traits associated with approach related behavior and are motivated by rewarding stimuli may then be at a higher risk for maintaining, or increasing, smoking behavior. In turn, high disinhibition, high reward motivation nondaily smokers may be more likely to take risks and engage in behavior consistent with risk-taking immediately after smoking a cigarette. While young adult ITS
in the current study did not appear to take greater momentary risks on a cognitive task related to reward seeking (i.e., mBART) after smoking a cigarette, nondaily smokers who reported higher levels of pathological disinhibition did appear to have increased momentary risk-taking during nonsmoking occasions. More importantly, nondaily smokers with higher pathological disinhibition and increased motivation for nondrug incentives reported significantly higher adventurousness immediately after smoking a cigarette, but not after nonsmoking surveys. Therefore, higher disinhibition and reward motivation are uniquely associated with increased experience of sensation seeking (i.e., adventurousness) immediately after cigarette consumption. The maintenance, and potential escalation, of smoking behavior could be related to “peak seeking” and could potentially increase the prevalence of a number of concurrent negative health behavior choices related to broad personality traits such as disinhibition. In particular, increased disinhibition may relate to poor decision-making when in the presence of rewarding stimuli, including the acute effects of nicotine (Castellanos-Ryan, et al., 2011; Perkins, et al., 2008). Additionally, the significant association between increased reward motivation and higher self-reported adventurousness after smoking cigarette can help to characterize addiction in nondaily smokers. Traditional conceptualizations of addiction, based primarily on daily smokers, highlight a decreased response to monetary rewards (Wilson, et al., 2008). Accordingly, increased sensitivity to nondrug rewards has been previously identified as a protective mechanism against nicotine addiction (Buhler, et al., 2010); however, higher reward motivation may increase sensation seeking while experiencing the effects of nicotine which could motivate continued smoking behavior. Finally, the significant relationship between disinhibition and “dizzy” sensations after
smoking a cigarette is preliminary evidence for physical sensations related to nicotine consumption that may maintain smoking behavior. The implications for these findings, as well as limitations and future directions are described below.

A novel aspect of the current study was the development of a mobile version of the BART. While ITS do not appear to reliably take greater risks immediately after smoking a cigarette, the study protocol is a proof-of-concept that it is possible to measure reward seeking behavior on a momentary scale. Risk taking and sensation seeking in young adults and adolescents are frequently associated with many behaviors that are considered detrimental to personal health and safety (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Steinberg, 2004; Steinberg et al., 2008). Importantly, the social context in which risky-behaviors occur seems to be an important determinant of risk-taking (Steinberg, 2004). For example, using a digital peer version of the BART, MacLean et al. (2013) reported that participants exposed to a risk-encouraging message from a digital peer increased risk-taking on the BART. In contrast, participants who passively viewed elevated riskiness by a digital peer without receiving a message from them (i.e., observing risk-taking devoid of social interaction) did not increase risk-taking behavior (MacLean, Geier, Henry, & Wilson, 2013). Another recent study by Bramms et al. (2014) examined neural correlates of reward processing in a large sample aged 8 to 25. Activation of the ventral striatum was related to reward motivated behavior in mid- to late-adolescence; however, this relationship seemed to be dependent on the social context (i.e., who was benefiting from the reward) of risk-taking behavior (Braams, Peters, Peper, Guroglu, & Crone, 2014). These findings support the conceptual importance of measuring momentary risk-taking using mobile applications,
such as the mBART, that can be implemented into real-world assessments using an EMA protocol. Most importantly, measuring risk-taking on a momentary scale in an individual’s natural environment affords the opportunity to also capture the potential influence of social interaction and other relevant contextual variables. Additional research examining the influence of social variables on risk-taking behavior under natural conditions using tasks such as the mBART may provide valuable insight into the process underlying impulsive decision-making.

One potential explanation for the negative findings with respect to reward seeking behavior in young adult ITS after smoking a cigarette is the inflation options used in the mBART application. The set value for price per pump (i.e., 5 cents) and an explosion point of 64 pumps were selected to remain consistent with the parameters most commonly used in the BART literature. However, these values may not be sufficient to capture risk-taking on a momentary scale. Other researchers have adapted modified versions standard BART to answer specific research questions related to behavioral risk-taking. For example, after decreasing the explosion break-point (thereby increasing the explosion probability), Vigil-Colet (2007) reported that average pumps on an expedited version of the standard BART was still significantly related to functional impulsivity (defined as a tendency to make quick decisions for personal gain) (Vigil-Colet, 2007). Using an expedited version of the mBART on a smartphone would decrease the amount of time engaged in the task, which is an important consideration in EMA research. Other possible changes include increasing the price earned per pump to better measure momentary risk-taking. For example, White et al. (2007) reported that traits related to behavioral approach and incentive motivation were associated with risk
on the BART using three different balloon types that varied only in the price per pump (i.e., .05 cents, 1 cent, 5 cents). Correlations between trait incentive motivation and average adjusted pumps on BART increased in magnitude as reward value increased, with the strongest association occurring at the 5 cents per pump value (White, Lejuez, & de Wit, 2007). Therefore, increasing the price per pump or including multiple balloon types that vary the price per pump may offer alternative options for using the mBART that would better capture relationships between disinhibition traits and momentary risk-taking. As such, decreasing the balloon break-point and increasing the price earned per pump may result in greater engagement in the task and potentially a clearer picture of momentary risk-taking in ITS and a variety of other developmental or clinical populations associated with risk-taking.

Similar to risk-taking, sensation seeking is a personality trait associated with a preference for novel and stimulating experiences to maintain optimal arousal (Zuckerman, Bone, Neary, Mangelsdorff, & Brustman, 1972). Individuals who report high levels of sensation seeking exhibit psychophysiological reactions (e.g., elevated heart rate) consistent with engagement in adventurous or dangerous activities (Zuckerman, 1990). Elevated sensation-seeking has been shown to differentiate smokers from nonsmokers (Carton, et al., 1994; Gurpegui et al., 2007; Spillane, Smith, & Kahler, 2010; Zuckerman, 1990) and, in smokers, is related to experience of nicotine withdrawal (Lee, et al., 2011), positive outcome expectancies of smoking (Urban & Demetrovics, 2010), pleasant experiences of smoking (Urban, 2010), and appetitive cue-induced craving (Doran, Cook, McChargue, & Spring, 2009). In a population of smokers, Zuckerman et al. (1990) reported a significant positive association between
high sensation seeking and smoking in social situation and a significant negative correlation between sensation seeking and heavy smoking (i.e., increased number of cigarettes per day and smoking early in the morning) (Zuckerman, Ball, & Black, 1990). These findings support a link between cigarette smoking and sensation seeking that may relate to the context in which smokers consume cigarettes. In particular, a tendency to be stimulated by adventurous behaviors may be associated with increased pleasure from the effects of nicotine or the behavior of smoking. Therefore, low-level smokers (such as ITS) may smoke to experience rewarding (positive) emotion or enhance the stimulus value within a potentially rewarding social environment.

Young adult smokers represent a particularly important population because sensation seeking in this developmental window is positively associated with general deviance, including licit and illicit drug use (Newcomb & McGee, 1991), and a sharp increase in nondaily smoking behavior (Pierce, et al., 2009). More recent research by Balevich et al. (2013) reported that college aged smokers score higher on sensation seeking measures compared to “never smokers” and “triers” (i.e., less than 100 lifetime cigarettes). Interestingly, these three groups do not differ on behavioral measures of nondrug reward sensitivity, such as delayed discounting and gambling tasks (Balevich, Wein, & Flory, 2013). While the authors did not differentiate among levels of cigarette consumption, the study provides partial support for the current study results demonstrating the potential for unique relationships between disinhibition and nondrug reward motivation in young adult ITS. Finally, a longitudinal study of 6522 US adolescents (aged 10-14 at baseline) reported that over two years, sensation seeking significantly predicted established smoking behavior at one or more follow up interviews.
Established smoking behavior was defined as smoking over 100 lifetime cigarettes, a criterion that has successfully differentiated experimental smokers from daily and nondaily smokers (Tracy et al. 2012). The authors highlight sensation seeking as a potentially valuable tool to identify adolescents at risk for establishing smoking behavior (Sargent, et al., 2010). The above studies demonstrate the value of using a global measure sensation seeking to investigate mechanisms associated with a preference for adventurous stimuli and smoking behavior. Accordingly, momentary sensation seeking after smoking a cigarette may provide a more relevant assessment of peak seeking behavior that conveys a risk for increasing or maintaining cigarette smoking behavior in young adult ITS.

In the current study, self-reported “adventurousness” on smoking and beeped surveys was included to capture a momentary inclination towards sensation-seeking activities. The results highlight increased self-reported adventurousness in ITS that endorse higher disinhibition and higher incentive motivation after smoking a cigarette compared to beeped (i.e., nonsmoking) surveys. The relationship was not mediated by reward motivation; instead, disinhibition and reward motivation uniquely predict self-reported adventurousness after smoking a cigarette. These findings lend credibility to the notion that some ITS may be motivated by peak seeking as a result of smoking a cigarette. According to this logic, ITS who report a propensity to engage in behaviors without forethought may be more inclined to seek out risky or adventurous behaviors while experiencing the effects of nicotine. Examples of such behaviors could be using other substances, drinking, or increased involvement in social behaviors. A large study by Ramo et al. (2012) revealed that, compared to those who smoke only tobacco,
college students who co-use marijuana and tobacco were significantly more likely to be nondaily smokers and report increased alcohol and drug use. The authors highlighted the need to understand factors related to co-use of tobacco and marijuana, such as personality characteristics, to reduce the negative health impact of tobacco use on young adults (Ramo, Delucchi, Hall, Liu, & Prochaska, 2013). Additionally, college aged nondaily smokers endorse higher rates of secondary dependence motives (e.g., social goads, positive reinforcement etc.) compared to daily smokers (Piasecki, et al., 2007). Taken together, these relationships raise the possibility that incentive motivation and personality have a differential effect on momentary adventurousness that may be related to smoking maintenance in ITS and potentially a host of associated behaviors. The broader implication is that this information can then be used to develop or evaluate treatment interventions that have been typically applied to traditional conceptualizations of addiction.

The current results also suggest that ITS who are motivated by nondrug rewards may also engage in behaviors associated with peak seeking and adventure. One important application of incentive motivation within addiction treatment is contingency management. Contingency management treatment is an empirically supported treatment approach that utilizes nondrug rewards (such as money) as reinforcers to motivate sustained abstinence (Prendergast, Podus, Finney, Greenwell, & Roll, 2006). The underlying premise of contingency management relies on sufficiently reinforcing nondrug incentives that are offered on a schedule incompatible with drug use (e.g., as rewards for not using) to decrease the frequency of substance use. Despite a wealth of supporting literature (see: Prendergast, Podus, Finney, Greenwell, & Roll, 2006), a
recent study has suggested that contingency management interventions offer only
short-term gains that are no longer significantly different from alternative treatment
strategies after two months (Ledgerwood, Arfken, Petry, & Alessi, 2014). Extended to
the current findings, the relationship between nondrug reward motivation and
momentary self-reported adventurousness after smoking a cigarette may reflect one
potential avenue for treatment (i.e., increase monetary reward to satisfy momentary
sensation seeking); however, it may also be important to consider how broader
pathological disinhibition influences momentary adventurousness after smoking a
cigarette. Exploration of both interventions using nondrug rewards and interventions
addressing behaviors associated with disinhibition, specifically as they relate to the use
of substances, may provide more comprehensive interventions that achieve longer
lasting abstinence than traditional withdrawal focused treatment.

Another important momentary aspect of addictive behavior is the physiological
effect of the substance immediately after consumption. The subjective effects of nicotine
are well characterized (Kalman, 2002; Perkins et al., 1994; Rose, Behm, Westman,
Bates, & Salley, 2003), but the individual experience of positive or negative sensations
after nicotine administration can be subtle (Rose, Behm, Westman, & Johnson, 2000)
and may vary by smoking intensity (Fant, Schuh, & Stitzer, 1995). Perkins et al. (2000)
administered intranasal nicotine in a population of heavy smokers and nonsmokers
(less than 100 lifetime cigarettes). Notably, visual analogue scale ratings of “head rush”,
“arousal”, and “pleasant” were positively associated with experience seeking and
disinhibition in nonsmokers after intranasal nicotine administration (Perkins, Gerlach,
Broge, Grobe, & Wilson, 2000). Although young adult ITS have considerably more
experience with nicotine than nonsmokers, the results demonstrate a potential mechanism by which individuals may initiate and then maintain low levels of smoking behavior. The current results suggest that increased disinhibition in young adult ITS is predictive of increased dizzy sensations immediately after smoking a cigarette. Therefore, ITS smokers who endorse characteristics associated with behaving rashly without thinking of consequences are more likely to experience specific subjective effects of nicotine which may lead to a continuation or escalation of smoking behavior. Interestingly, subjective experience of “rush”, commonly thought of as a positive effect of nicotine, was not related to disinhibition or reward motivation. These findings are preliminary and should be interpreted as potential motivators for ITS smoking behavior. Additional research is needed to elucidate the links between disinhibitory personality and a more comprehensive evaluation of momentary subjective effects associated with nicotine administration in ITS.

In addition to changes to the mBART settings described above, the current research study is not without several important limitations. First, the time duration of EMA may not have been long enough to sample adequate smoking instances. By definition, ITS do not consume cigarettes on a regular basis; therefore, a longer EMA data collection period would increase the probability of capturing more smoking instances to highlight motivational factors related to continued smoking behavior. Recent research investigating ITS has used upwards of 21 days to capture EMA data related to smoking events (Shiffman, Tindle, et al., 2012). Second, the rewarded antisaccade task may not be the ideal measure to capture the motivational aspects of nondrug rewards in this population. The rewarded antisaccade task has successfully
been used to differentiate the impact of incentives across development (Geier & Luna, 2009; Geier, 2013), smoking status (Geier, et al., 2014), and mood disorders (Jazbec, et al., 2005). However, the rewarded antisaccade task may not be sensitive to capture individual differences within a single population of ITS, which may be more variable than those listed above. Future research may want to compare rewarded AS performance to a control group (i.e., nonsmokers or heavy smokers) to clarify the motivational effect of incentives on a cognitively challenging task that is likely due to nondaily smoking and separate effects related to developmental stage (i.e., young adulthood). Finally, the sample for the current research study was predominantly Caucasian (77%). Recent epidemiological studies highlight a significant proportion of ITS identify as minorities, particularly Black and Hispanic (Wortley, Husten, Trosclair, Chrismon, & Pederson, 2003). A more diverse sample would improve the generalizability of the findings to better match the broader population of ITS. Notwithstanding these limitations, the current study is an important step to identifying factors related to smoking maintenance and potential barriers to abstinence in nondaily smokers.

The primary hypothesis that reward sensitivity mediates the relationship between pathological disinhibition and the subjective effects of nicotine and reward seeking behavior was not supported; however, potentially important relationships between momentary factors after smoking a cigarette and disinhibition and reward motivated cognitive control may provide insight into smoking maintenance in young adult ITS. Nondaily smokers are likely not motivated by traditional conceptualizations of addiction (e.g., withdrawal avoidance). Instead, smoking behavior in ITS may be better conceptualized as “peak seeking” or smoking to experience the positive effects of
nicotine. This behavior could be further enhanced by a characterological propensity to engage in actions without forethought (i.e., disinhibition) and sensitivity to rewarding stimuli. The relationship between self-reported adventurousness and disinhibition and reward motivation may provide preliminary insight into this potential mechanism maintaining smoking behavior. Namely, after smoking a cigarette, young adult ITS may be more inclined to engage in behaviors associated with adventure, danger, or excitement. Therefore, those who have higher disinhibitory characteristics and sensitivity to monetary reward may be at an increased risk for experiencing excitement after smoking a cigarette. If true, cessation intervention focused on the avoidance of withdrawal symptoms would likely not address factors that are associated with cigarette consumption in young adult ITS. In fact, the results may highlight heterogeneity within nondaily smokers that is an important consideration for treatment. Specifically, individual differences in pathological disinhibition and reward motivation can be used in treatment to address factors that may be related to smoking behavior, but are not captured by traditional addiction criteria such as withdrawal. Targeted intervention aimed at cognitive processes related to rewarding stimuli and a propensity to engage in risky behavior might then provide effective avenues to address maintenance of nondaily smoking behavior.

Future research investigating the specific mechanism of smoking maintenance will help clarify motivators of smoking maintenance in ITS. One important consideration is that many nondaily smokers may not readily identify as a smoker and may exhibit less interest in quitting than daily smokers (Hassmiller, et al., 2003). This does not diminish the importance of investigating factors related to smoking, particularly because
of the relationship to broader characterological traits. Therefore, studies that evaluate the context of smoking behavior and other negative health behaviors related to nondaily smoking could identify additional targets for intervention. Most notably, co-use of tobacco with other drugs and alcohol is a critical avenue for further investigation. Recent research has demonstrated links between nondaily smoking and marijuana use (Ramo, et al., 2013) and alcohol consumption (Barrett, Campbell, Roach, Stewart, & Darredeau, 2013). Nondaily smoking may provide one avenue to address other negative health decisions in young adults that may be associated with increased pathological disinhibition and reward motivation. Likewise building on the neuroimaging literature associated with daily smokers may also provide more insight into mechanisms related to smoking maintenance in ITS. Specifically, as outlined in the introduction, functional activation of the striatum has long been associated with addiction and the progression of addictive behavior (Koob & Volkow, 2010). Increased activation of the striatum, especially in comparison to nonsmokers or daily smokers, may then provide additional evidence for “peak seeking” beyond behavioral response to rewarding stimuli. The use of fMRI offers several advantages including to ability to evaluate functional connectivity between reward and control-related brain regions. For example, college aged ITS and nonsmokers may exhibit similar behavioral sensitivities to rewarding stimuli that may be characteristic of young adulthood. However, ITS may have reduced functional connectivity between reward and control-related regions that could be associated with other relevant factors (e.g., personality, other substance use, etc.). Finally, more longitudinal research is needed to evaluate smoking behavior in young adult nondaily smokers and potential factors related to the escalation (or stabilization, cessation) of
cigarette use. This includes investigation related to cigarette use trajectory throughout young adulthood, but also more extensive evaluation of cigarette smoking behavior within individuals using EMA. Young adult smokers may be particularly amenable to such research, as they frequently use smartphones and digital media to communicate and connect with important people and information.

In addition to research examining naturally-occurring patterns of behavior, the integration of EMA into a treatment setting could help individualize targets for smoking cessation in the broader context of treatment. Using the above research as a model, treatment providers could provide patients with a smart phone prior to treatment (e.g., 7 days). During this time, the patient will provide extremely valuable data surrounding use patterns, emotional state, drug motivators, and many other factors associated with smoking in their natural environment. This information can then be used to develop individualized treatment content that can be used in conjunction with empirically supported treatment approaches. The use of mobile phone technology has been associated with promising results in smoking cessation and anxiety treatment research (Ehrenreich, Righter, Rocke, Dixon, & Himelhoch, 2011). Given the sharp rise in young adult nondaily smoking, applications of EMA to this population can help address an emerging public health concern. Continued research on motivational factors associated with smoking maintenance in ITS can help reduce the possibility of escalating cigarette use and potentially encourage abstinence early in the trajectory of use. Such interventions can then be applied to varying frequencies of cigarette use and other drugs of abuse.
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