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EVALUATING BEHAVIORAL DIMENSIONS OF SMOKER REWARD PERCEPTIONS

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ABSTRACT

Nicotine is a very addictive component of cigarettes that can affect a smoker's value system, such that he or she places a high priority on the opportunity to smoke a cigarette. As a result, the value of other types of rewards are diminished. Previous studies suggest that trait impulsiveness, levels of nicotine dependence, and the severity of the aversive affective symptoms produced by acute nicotine withdrawal all influence smoking behavior in important ways. While these factors have been examined separately, there has not been much research examining how these variables relate to one another. The aim of this thesis was to address the knowledge gap by exploring the associations among impulsivity, sensitivity to reward, affective state, and nicotine dependence. In the current study, participants were asked to answer questionnaires about their moods, attitudes, and habits of their smoking behaviors. Results indicate that significant correlations exist between a smoker's mood and reward perception, impulsivity and reward perception, and higher levels of acting on impulse leading to lower levels of ability to inhibit impulses. Additionally, a correlation exists between smoking consistency and rigidity in regards to a smoker's habits. Understanding reward processing for smokers can assist in determining different types of treatment methodologies that can be used for smokers attempting to quit in order to modify their smoking behaviors.

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Introduction

Cigarettes have addictive properties in them, such as nicotine, that cause smokers to have intense cravings for them, even after abstaining for a brief period of time (Stolerman & Jarvis, 1995). From a neurobiological standpoint, nicotine is known to be a psychoactive agent that has numerous positive effects on mood and cognitive function, while also being a positive reinforcer (Benowitz, 2008). In rodent studies, there has been evidence that nicotine addiction is mediated by central dopamine systems (Barrett, 2004). Nicotine diffuses into brain tissue where it subsequently binds to ligand-gated ion channels known as nicotinic acetylcholine receptors (nAChRs) (Dajas-Bailador & Wonnacott, 2004). The binding allows an agonistic effect on nAChRs, in which the channels open to allow cations, such as sodium and calcium, to enter.

The release of various neurotransmitters occurs following the binding of nicotine to nAChRs, but the release of dopamine has been found to be of particular importance due to the downstream effects it has on reward-related pathways in the brain (Dani and De Biasi, 2001). This effect is amplified by the observance that enzymes monoamine oxidase A and B, which degrade dopamine, are at lower levels during chronic cigarette smoking (Brody, 2006). As a result, dopamine has a longer lifetime in the synapse to further stimulate dopaminergic receptors and contribute to the enhanced addictive effects observed in terms of reward perception for smokers.

Another inhibitor of dopamine is γ-aminobutyric acid (GABA). The nAChRs located on GABA neurons are desensitized at a faster rate compared to the nAChRs located on dopamine neurons, so the inhibitory effects of GABA on dopamine are no longer effective when exposed to acute levels of nicotine (Laviolette and van der Kooy, 2004). Consequently, a bypassing mechanism can be observed in which dopamine neurons can be acted upon by nicotine without inhibition, which in turn leads to a net increase in dopamine activity. Nicotine also exhibits the effects of decreasing the threshold necessary in order for intracranial self-stimulation (ICSS) (Cryan, Bruijnzeel, & Skjei, et al., 2003) while the ICSS threshold increases during periods of withdrawal (Epping-Jordan, Watkins, & Koob, et al., 1998). Therefore, the uptake of nicotine has been critical in understanding the mechanisms of drug-based rewards.

Neuroadaptation has been found with repeated nicotine exposure in which there is an increase in nicotinic binding sites in the brain (Lapchak, Araujo, & Quirion, et al., 1989). This has been related to studies indicating that the upregulation of these receptors may be due to continued exposure to nicotine which can induce the effects of desensitization of nAChRs (Fenster, Whitworth, & Sheffield, et al., 1999). These aspects may be related to nicotine tolerance in which constant nicotine exposure promotes desensitization of those receptors and the response in the brain is to create more receptors. When these receptors are no longer desensitized through abstinence, withdrawal and craving symptoms are established and exposure to nicotine can again induce desensitization. This effect may tie in to the theory that smokers regulate their smoking patterns in order to ensure that nAChRs in the brain are maintained in a desensitized state so that the discomforting effects of withdrawal from abstaining are not experienced (Dani and Heinemann, 1996). Therefore, modulating smoking activity can regulate levels of nicotine in the brain and subsequently modify various nAChRs classes with the net result of obtaining the rewarding effects of smoking and increased motivation for the next smoking opportunity (Kenny & Markou, 2001). Anecdotal reports have shown that smokers usually enjoy the first cigarette in the morning the most due to abstaining from nicotine while sleeping whereas chronic smoking does not affect the overall hedonic values experienced (Laviolette & van der Kooy, 2004). Therefore, an interconnectedness between reward mechanisms, increase in nAChRs, and a motivation to desensitize those nicotinic receptors may be root factors in determining nicotine dependence.

Certain individuals may be more susceptible than others to developing nicotine dependence as a result of the mechanisms described above. Research indicates that trait impulsiveness is an individual trait that is particularly important when it comes to influencing smoking behavior and associated nicotine dependence (Ryan, MacKillop, & Carpenter, 2013). Consistent with this idea, smokers scored higher than nonsmokers on measures involving aspects of impulsivity (Bickel, Odum, & Madden, 1999) and greater impulsivity was related to increased rates of relapse to smoking (Doran, Spring, & McChargue, et al., 2004). The impulsivity to smoke can be conceptualized in relation to results found by Hogarth et al. (2010) in which high levels of motor impulsivity may accelerate the rate of transition to automatic drug self-administration. Additionally, impulsivity may be related to reward perception for smokers; Perkins et al. (2008) found that trait impulsivity influenced the subjective rewarding effects of nicotine. Since nicotine dependence has aspects related to impulsivity, people who are impulsively predisposed may turn to cigarettes in order to achieve the short-term rewards associated with the intake of nicotine. Impulsive decision-making that is characterized by a predisposition towards pursuing short-term rewards may affect the long-term perception of smokers, leaving them less cognizant of the detrimental effects of smoking. As a result, the effects of nicotine from smoking cigarettes may present a stronger motivating factor to more impulsive individuals to continue pursuing smoking opportunities. Collectively, these factors (i.e., the fact that impulsive individuals are more sensitive to nicotine, the observation that certain individual's impulsivity in decision-making is driven towards short-term rewards, and the potential match between this desire and the effects produced by cigarette use) may help to explain why some individuals are more likely than others to begin smoking cigarettes and to develop nicotine dependence as a result.

Reward sensitivity is a characteristic that varies across individuals and that is conceptually related to impulsivity. Furthermore, like impulsivity, reward sensitivity has implications for the development of smoking. Reward sensitivity refers to the level of reactivity that an individual experiences when he or she receives a reward. In one rat study, rats consumed nicotine in order to increase the sensitivity of brain reward systems and subsequently amplify the rewarding effects of ICSS (Kenny & Markou, 2006). Therefore, the reinforcing properties associated with nicotine are dependent on its ability to exert its influence in brain circuitry, particularly dopaminergic pathways responsible for sensitivity to natural rewards (Rice & Cragg, 2004). Additionally, excessive stimulation of nicotine can lead to adaptations in brain reward circuitry that result in the development of compulsive drug use (Ahmed, Kenny, & Koob, et al., 2002). Smokers who are highly sensitive to rewards – just like those who are highly impulsive – may be driven to smoke in part to obtain the short-term effects of nicotine. Nicotine affects the dopaminergic pathways of the brain through nAChR desensitization to increase reward-related firing, but suppresses such firing in the absence of rewards (Rice & Cragg, 2004). The synaptic mechanisms associated with nicotine administration are thought to play a key role in the development of nicotine dependence (Mansvelder, Keath, & McGehee, 2002). Therefore, individuals who are more sensitive to rewards may turn to smoking in order to receive the immediate satisfaction associated with smoking, while being conditioned during the process to learn the reward value of cues associated with the action.

From a situational standpoint, cigarette availability (the degree to which smokers anticipate having access to cigarettes) is a contextual variable that strongly influences how smokers respond to cigarette-related and non-drug rewards. For example, in a study done by Droungas et al. (1995), smokers were divided into two groups in which one group was told they would be able to smoke after the study while the other group was told they would not. Compared to those who did not expect to smoke, individuals who were expecting to smoke after the study reported higher levels of smoking desirability and withdrawal symptoms, especially when presented smoking-related cues compared to the baseline. Therefore, cigarette availability appears to amplify the desire to smoke among smokers, and this effect appears to be augmented even further by smoking-related cues. Importantly, cigarette availability appears to have the opposite effect on non-drug rewards. Specifically, using functional magnetic resonance imaging (fMRI), Wilson et al. (2008) found that smokers who expected an opportunity to smoke soon showed lower response to nondrug (monetary) rewards in the caudate nucleus (a key part of the so-called reward system of the brain) compared to smokers who did not expect to have an opportunity to smoke in the near future (Wilson, Sayette, & Delgado, et al., 2008). Thus, cigarette availability appears to alter how smokers respond to both cigarette cues and nondrug rewards, increasing the salience of the former and decreasing sensitivity to the latter.

A second situation variable that influences reward-related behavior in smokers is nicotine withdrawal. When smokers attempt to quit smoking, they experience withdrawal symptoms that are related to their degree of dependence on nicotine (Fagerstrom, Heatherton, & Kozlowski, 1990). Essentially, these withdrawal symptoms are a variety of discomforts that smokers experience when they have abstained from smoking for a period of time. The discomforts from a variety of studies show that the withdrawal symptoms are widespread for those who abstain from smoking (Cummings, Giovino, & Jaén, et al., 1985). The severity of these symptoms can vary depending on the length of abstinence from nicotine and the history of nicotine use. In animal studies, the severity of nicotine withdrawal signs was proportional to the level of nicotine exposure, with those with higher amounts of nicotine exhibiting more severe symptoms (Malin, Lake, & Newlin-Maultsby, et al., 1992). However, Shiffman & Jarvik (1976) showed that nicotine withdrawal symptoms associated with abstaining from cigarettes were not uniformly severe across a 12-day period following the onset of smoking cessation. Some aspects of withdrawal decreased linearly in the first few days of abstaining and then leveled off afterwards, while other aspects of withdrawal showed a U-shape curvature for severity (i.e., decreasing in severity across the first few days of abstinence, followed by increase in strength over subsequent days). Nicotine withdrawal is associated with clear physical symptoms, such as a decline in heart rate and increased levels of eating and subsequent weight gain (Hughes, Higgins, & Bickel, 1994). However, research indicates that the affective symptoms associated with nicotine withdrawal are particularly important from a clinical perspective. Specifically, many smokers experience a variety of negative mood symptoms (e.g., irritability, restlessness) when they abstain from nicotine (Taylor, Ussher, & Faulkner, 2007). Addressing these affective symptoms is a key component of successfully treating smoking, as the negative affect associated with nicotine withdrawal is a powerful motivator for resuming cigarette use (Benowitz, 2008).

In sum, research suggests that individual differences in impulsiveness influences nicotine dependence severity in individuals who smoke cigarettes. Specifically, studies have demonstrated that trait impulsiveness is positively associated with level of nicotine dependence. As alluded to above, the link between individual differences in impulsiveness and nicotine dependence may be related to underlying variability in the functioning of brain reward systems (e.g., high impulsiveness may be produced in part by greater sensitivity in the brain reward system, which in turn is associated with a more positive response to acute nicotine administration). These connections may be further shaped by the extent to which individuals are experiencing the aversive affective symptoms (i.e., the increase in negative affect and/or decrease in positive affect) associated with nicotine withdrawal. While these factors have been examined separately, there has not been much research examining how these variables relate to one another. The aim of this thesis was to address the knowledge gap by exploring the associations among impulsivity, sensitivity to reward, affective state, and nicotine dependence. Finally, because cigarette availability has been shown to affect reward-related functioning in smokers, these relationships were examined using data from a sample of smokers who were explicitly informed that cigarettes would not be available during the study.

Methods

Participants

A total of 62 participants were used in the study (n = 62). They were recruited through various methodologies such as flyers, radio advertisements, newspaper advertisements, and online advertisements throughout the Penn State area. Out of the total 62 participants, 36 of them were male and 26 were female. The mean age of the participants was 25.61 years with a range of 18 to 42 (SD = 6.65). The smoking participants smoked an average of 14.96 (SD = 3.39) cigarettes per day with a range of 10 to 20. The participants were prescreened in order to determine eligibility for the study. Of the 62 individuals enrolled, 44 completed all study procedures; the remaining 18 participants completed only portions of the study. Each analysis was based on all available data (sample size per test varies from 44 to 62 participants.) All participants signed a written, informed consent form and the study was approved by the Institutional Review Board through The Pennsylvania State University.

Questionnaires

Participants completed a series of questionnaires regarding various aspects of their smoking behavior and effects observed due to that behavior. The following questionnaires were analyzed in this study:

Nicotine Dependence Syndrome Scale (NDSS).

Developed by Shiffman, Waters, & Hickcox in 2004, the NDSS is a multidimensional questionnaire designed to measure nicotine dependence (Shiffman, Waters, & Hickcox, 2004). The NDSS measures the five core aspects of tobacco addiction which include: 1) the compulsion to smoke due to a craving and a desire to avoid withdrawal symptoms (Drive); 2) preference for smoking over other types of reinforcers (Priority); 3) lower levels of sensitivity to the effects of nicotine and smoking (Tolerance); 4) the establishment of consistency and regularity of smoking patterns (Continuity); and 5) smoking behavior that is rigid and insensitive to contextual factors (Stereotypy) (Shiffman, Waters, & Hickcox, 2004).

The NDSS includes twenty-seven items that are used to assess their current dependence to nicotine, which are comprised of statements such as, "I smoke just about the same number of cigarettes from day to day." Participants are instructed to rate how well each statement applies to them on a scale from 1 to 5, with 1 representing "Not at all true" and 5 representing "Extremely true." Four statements are reversed scored. Additionally, two more statements were presented for which the participants could make a rating of 6, which corresponds to "Does not apply." Finally, participants were also asked to enter an amount of money they would pay for one cigarette if they could not obtain any cigarettes for an entire day (this item is not a focus of the present theses).

Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ).

Developed by Torrubia and Tobena in 1984, the SPSRQ is a set of brief self-report measures which are intended to assess individual differences in personality qualities that reflect the sensitivity of two physiological self-regulatory systems (Torrubia & Tubena, 1984). These systems are based on the concepts of Gray's model of brain functions and behavior, which consists of the Behavioral Inhibition System (BIS) and Behavioral Approach System (BAS) (Gray, 1970). BAS is involved in regulating appetitive motives in which the goal is to move toward something desired (e.g., a potential reward), while BIS is involved in regulating aversive motives in which the goal is to move away from something unpleasant (e.g., a potenital punishment). BAS can be subdivided into three categories: drive, fun-seeking, and reward responsiveness. Each subsection within BAS has statements that are focused particularly on analyzing how individuals respond to positive aspects in these regards. However, BIS is not divided and the corresponding statements are focused particularly on analyzing how individuals respond to negative situations. The SPSRQ was developed to create specific self-report measures of the reactivity and responsivity of these systems (Torrubia & Tubena, 1984).

The SPSRQ includes 48 questions (e.g., "Would you like to be a socially powerful person?"). Participants are asked to answer "yes" or "no" to each question. No questions are reversed scored. Half of the questions are designed to assess sensitivity to punishment and the other half of the questions are designed to assess sensitivity to reward. The items are summed together to create a score for each scale.

Barratt Impulsiveness Scale (BIS-11).

Developed by Barratt et al. in 1959 and subsequently modified on many occasions (most recently by Patton et al. in 1995), the BIS-11 is a questionnaire designed to assess individual differences in personality and behavioral characteristics subsumed within the broad construct of impulsivity (Patton, Stanford, & Barratt, 1995). BIS-11 can be divided into various factors of different order that target specific aspects of impulsivity. Second order factors involve attentional, motor, and nonplanning aspects of impulsivity, while two first order factors are determined within each second order factor. The first order factors of attention and cognitive instability are found within the second order factor of attention. The first order factors of motor and perseverance are found within the second order factor of motor. The first order factors of self-control and cognitive complexity are found within the second order factor of nonplanning.

The BIS-11 consists of 30 questions like, "I plan for job security." The participants are asked to rate their response to each statement on a scale from 1 to 4, with 1 representing "Rarely or never" and 4 representing "Almost always or always." Eleven questions are reversed scored.

Positive and Negative Affect Schedule (PANAS).

Developed by Watson, Clark, & Tellegen in 1988, the PANAS is a mood scale designed to assess the degree to which individuals are experiencing positive and negative emotions over a time frame defined by the instruction set (e.g., today, the past week) (Watson, Clark, & Tellegen, 1988). The current study focused on the use of the PANAS to assess both state affect (PANAS-S), which corresponds to how the participant feels at the moment of questionnaire administration, and trait affect (PANAS-T), which corresponds to how participants feel in general (Watson, Clark, & Tellegen, 1988).

The PANAS consist of twenty affect-related words such as "alert" or "scared." The participants mark the extent to which they feel that way either at the present moment on a scale from 1 ("very slightly or not at all") to 5 ("extremely"). Each word corresponds to either a positive or negative emotion and the score assigned to each word is added to its corresponding category to get a sum score for positive and negative emotion. A higher score indicates a higher level of that particular emotion.

Procedure

The procedure for this study was broken into two separate sessions. Participants were instructed to smoke *ad libitum* prior the first session. During the first session, the participants first provided informed consent. Then participants were asked to complete screening procedures to determine eligibility to complete the full study. The first screening procedure involved the participants exhaling into a handheld monitor that measured the levels of carbon monoxide in their breath in parts per million (ppm) concentrations. To be eligible, the concentration of carbon monoxide had to be at least 10 ppm. Next, they were asked to fill out a form about whether they were experiencing any symptoms of depression. Afterwards, they were asked questions about their use of drugs and alcohol. Eligibility to complete the rest of the study was based upon the results of the screening.

If the participants were eligible for the study, buccal cell samples were collected using the following procedure. They were asked to rinse their mouth with water. After waiting for at least one minute, they were asked to rub ten cotton swabs against the inside of their cheeks (five on the right side of the mouth and five on the left side of the mouth) and then to place the samples in a vial. The vial was then placed into a leak-proof plastic bag. All samples were marked only with a bar code (linked to a unique code) and date of collection. Buccal cell samples were used for exploratory analyses of genes (DNA) that might play a role in cigarette smoking (which was not a focus of the current thesis).

Afterwards, participants completed two working memory tasks. The first was a computerized working memory task during which they were asked to solve some math problems and remember words. For the second task, they were asked to remember and repeat back letters that were read to them by an experimenter. Then, they were asked to complete questionnaires about their age, gender, mood, current and past smoking patterns, and their thoughts and attitudes about non-smoking factors, including the BIS-11, SPSRQ, NDSS, and PANAS-T. (As indicated previously, this study focuses on a specific subset of questionnaires; described in detail above.) Finally, they were asked to complete and sign an MRI safety screening form to ensure that it is safe for them to participate in MRI research.

After completing the aforementioned tasks, participants were scheduled for a second session. They were asked not to smoke or use any nicotine-containing products, such as nicotine gum, for 12 hours before the second session. Also, they were asked to abstain from drinking alcohol or using other drugs for 24 hours before the second session.

For the second session, the participants were first asked to provide another measure of the level of carbon monoxide in their breath by exhaling into the handheld monitor. Their carbon monoxide level was required to be half or less than what it was for the first reading in order to be eligible to complete the second session. Also, participants had to report that they have not smoked within the last 12 hours and that they have not used alcohol or recreational drugs within the last 24 hours. They were given an opportunity to reschedule the session one time if they did not meet those conditions. If they met the conditions, participants were explicitly instructed that they would not be permitted to smoke during the three-hour study. Next, they were asked to complete questionnaires asking about their mood, thoughts, and attitudes about smoking, including PANAS-S. After finishing those tasks, they were asked to complete tasks in an MRI scanner, followed by a final behavioral assessment. As these procedures are not a focus of this paper, they are presented only briefly below.

The MRI scanner used in the study was a 3.0 Tesla MRI scanner. During the scan session, participants were asked to perform a card guessing task that involved making guesses about the value of the playing cards seen on the screen. Participants earned up to an additional $30 based on their performance on the task. The computer kept track of the monetary reward accumulated during the card guessing task. The amount earned based on performance was added to the total money earned for participating. The MRI portion of the study lasted approximately 1 hour and 30 minutes.

After finishing the MRI portion of the experiment, participants were asked to complete a simple choice task for about 1 hour. Like the card guessing task described above, they had the chance to earn up to $10 extra based upon their performance on the choice task, which was added to the total payment for participation. Finally, they were debriefed and given an opportunity to ask question about the study. Altogether, the second session took approximately 3 hours to complete.

Results

NDSS

As previously mentioned, the NDSS is focused on determining five core aspects of nicotine dependence/addiction (Shiffman, Waters, & Hickcox, 2004). In regards to drive, the mean value was -0.72 with a standard deviation value of approximately 1.16. In regards to stereotypy, the mean value was 0.15 with a standard deviation value of approximately 0.76. In regards to continuity, the mean value was -0.11 with a standard deviation value of 0.91. In regards to priority, the mean value was -0.57 with a standard deviation value of 0.57. In regards to tolerance, the mean value was -0.03 with a standard deviation value of 0.96. The mean value for overall level of nicotine dependence was -0.61 with a standard deviation value of 0.72.

SPSRQ

As previously mentioned, the SPSRQ is designed to measure individual differences in the sensitivity to appetitive (reward-related) and aversive (punishment-related) stimuli (Torrubia & Tubena, 1984). In regards to factor 1, which corresponds to sensitivity to punishment, the mean value was 8.30 with a standard deviation value of 4.48. In regards to factor 2, which corresponds to sensitivity to reward, the average value was 12.48 with a standard deviation value of 4.85. Thus, sensitivity to reward was higher than sensitivity to punishment for the sample as a whole.

BIS-11

As previously mentioned, the BIS-11 assesses individual differences in personality and behavioral constructs related to impulsiveness (Patton, Stanford, & Barratt, 1995). In regards to the second order factor of attention, the mean value was 16.19 with a standard deviation value of 3.61. In regards to the second order factor of motor, the mean value was 22.60 with a standard deviation value of 4.07. In regards to the second order factor of nonplanning, the mean value was 24.03 with a standard deviation value of 4.47. In regards to the overall total score, the mean value was 62.82 with a standard deviation value of 9.69.

PANAS

As previously mentioned, the PANAS is designed to assess the degree to which individuals are experiencing positive and negative emotions (Watson, Clark, & Tellegen, 1988). The current study focused on the use of the PANAS to assess both trait affect (i.e., how participants feel in general; PANAS-T) when not deprived of nicotine, as well as state affect (i.e., how participants were feeling at the time of administration; PANAS-S) following acute nicotine deprivation. The mean value for the trait positive affect score was 36.07 with a standard deviation value of 5.62, while the mean value for the trait negative affect score was 16.86 with a standard deviation value of 5.11. The average value for the state positive affect score was approximately 30.59 with a standard deviation value of approximately 6.14, while the average value for the state negative affect score was approximately 18.98 with a standard deviation value of approximately 5.01. As seen from the mean values for trait and state emotion, participants reported experiencing higher levels of positive affect than negative affect. Additionally, consistent with expectations, nicotine withdrawal was associated with negative changes in affect, as indicated by a mean decrease in state positive affect (relative to the mean trait positive affect score) and a mean increase in state negative affect (relative to the trait negative affect score).

Correlations

As indicated above, the goal of this thesis was to investigate the associations among trait impulsiveness, trait sensitivity to reward and punishment, trait and state affect, and various facets of nicotine dependence. These associations were examined using Pearson bivariate product-moment correlations, which were calculated for all relevant variables (i.e., scores on the BIS-11, SPSRQ, PANAS-T, PANAS-S, and NDSS). Results are presented in Table 1, followed by additional details about and graphical presentation of significant correlations of interest to the study.

	PANAST_PA	PANAST_NA	PANASS_PA	PANASS_NA	SPSRQ_Rew	SPSRQ_Pun	BIS_Attention	BIS_Motor	BIS_Nonplanning	BIS_Total	NDSS_Drive	NDSS_Stereo	NDSS_Contin	NDSS_Prior	NDSS_Toler	NDSS_Overall
PANAST_PA	1															
PANAST_NA	-.03	1														
PANASS_PA	.48**	-.13	1													
PANASS_NA	-.02	.45**	-.11	1												
SPSRQ_Rew	-0.31*	.46**	-.28	.34*	1											
SPSRQ_Pun	.34**	.22	.18	.02	-.12	1										
BIS_Attention	-.09	.34**	.03	.09	.27*	.23	1									
BIS_Motor	.21	.27*	.21	-.07	-.21	.50**	.38**	1								
BIS_Nonplan	-0.26*	.40**	.06	.04	.24	.13	.56**	.42**	1							
BIS_Total	-.07	.43**	.13	.02	.12	.35**	.79**	.76**	.84**	1						
NDSS_Drive	-.16	.34**	-.06	.40**	.14	-.07	.17	.04	.07	.11	1					
NDSS_Stereo	.36**	-.03	.08	-.16	-.18	.03	-.23	.07	-0.30*	-.19	-0.28*	1				
NDSS_Contin	-.10	-.17	-.02	-.08	-.06	-.05	-.11	-.20	-.17	-.20	-.08	.22	1			
NDSS_Prior	.02	.00	-.09	.21	.10	.07	-.12	.01	-.01	-.05	-.03	-.23	-.17	1		
NDSS_Toler	-.03	.17	-.11	-.04	.22	.19	.16	.02	.29*	.20	-.16	-0.27*	.07	.11	1	
NDSS_Overall	.06	.43**	-.04	.33*	.16	.06	.12	.13	.03	.11	.84**	.07	-.02	.03	.10	1

**. Correlation is significant at the 0.01 level (2-tailed).
*.Correlation is significant at the 0.05 level (2-tailed).

Table 1. Pearson correlation coefficient matrix for the questionnaires used in the study

Table Key

PANAST_PA = PANAS-T Positive Affect

PANAST_NA = PANAS-T Negative Affect

PANASS_PA = PANAS-S Positive Affect

PANASS_NA = PANAS-S Negative Affect

SPSRQ_Rew = SPSRQ Sensitivity to Reward

SPSRQ_Pun = SPSRQ Sensitivity to Punishment

BIS_Attention = BIS Attention

BIS_Motor = BIS Motor

BIS_Nonplan = BIS Nonplanning

BIS_Total = BIS Total

NDSS_Drive = NDSS Drive

NDSS_Stereo = NDSS Stereotypy

NDSS_Contin = NDSS Continuity

NDSS_Prior = NDSS Priority

NDSS_Toler = NDSS Tolerance

NDSS_Overall = NDSS Overall

As mentioned above, it was observed that positive affect scores were higher than negative affect scores for both the trait and state versions of the PANAS. Additionally, participants were on average more sensitive to reward than punishment, as indicated by scores on the SPSRQ. There was a positive correlation between sensitivity to reward and state positive, $r(42) = 0.18$, $p = 0.25$; see Figure 1.

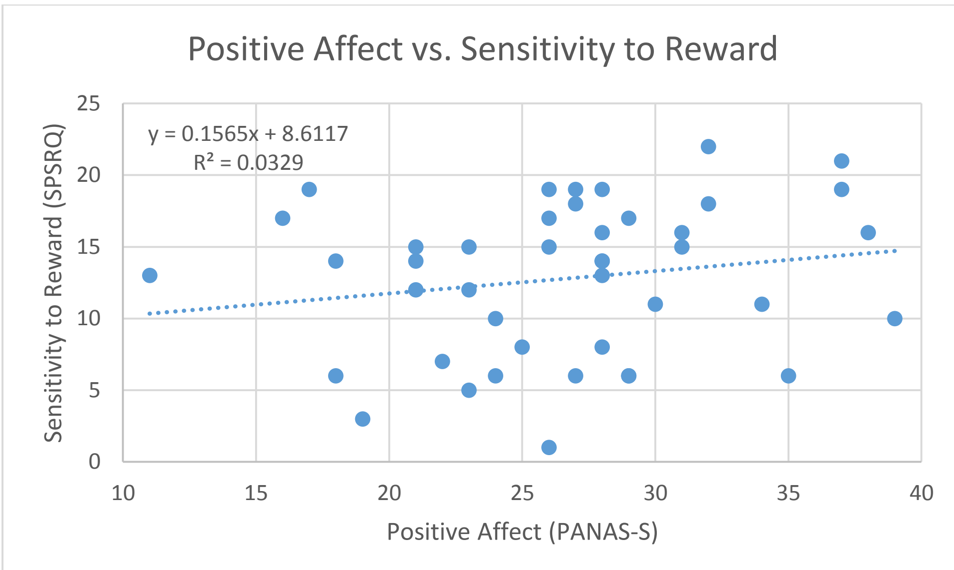

Figure 1. Positive Affect (PANAS-S) vs. Sensitivity to Reward (SPSRQ)

There was also a significant positive correlation between sensitivity to reward and state negative affect, $r(42) = 0.34$, $p = 0.03$; see Figure 2.

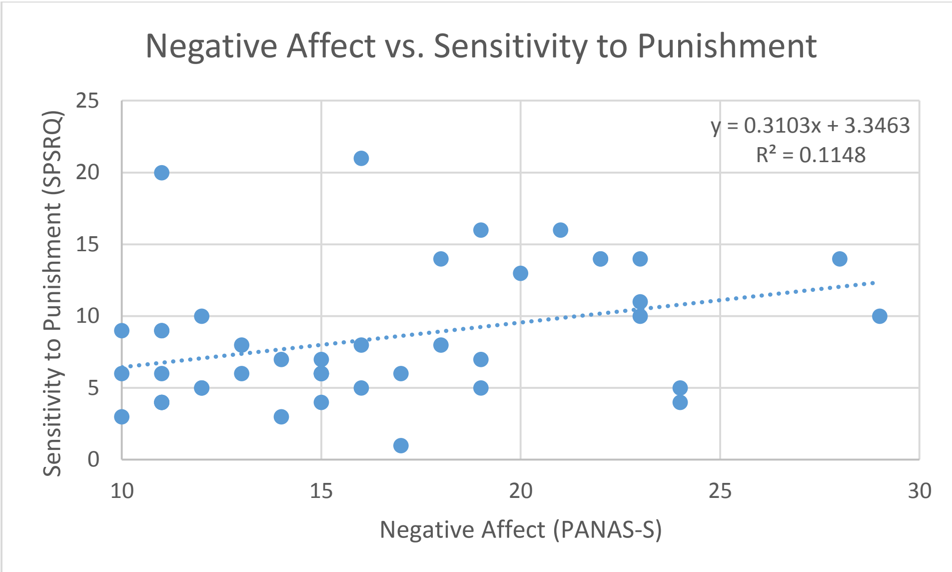

Figure 2. Negative Affect (PANAS-S) vs. Sensitivity to Punishment (SPSRQ)

There was a significant positive correlation between sensitivity to reward and trait positive affect, *r*(59) = 0.34, *p* = 0.01; see Figure 3.

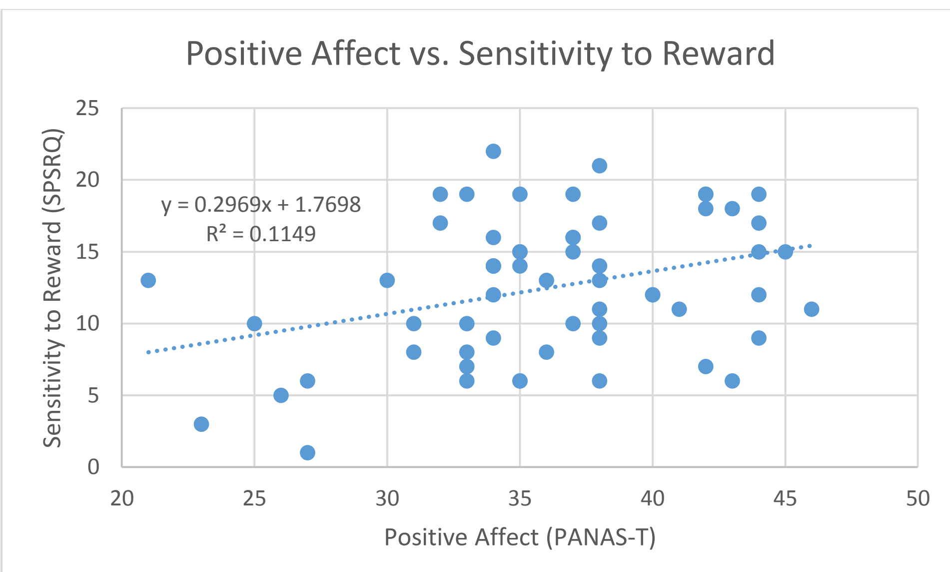

Figure 3. Positive Affect (PANAS-T) vs. Sensitivity to Reward (SPSRQ)

There was a significant positive correlation between sensitivity to punishment and trait negative affect, *r*(59) = 0.46, *p* < 0.001; see Figure 4.

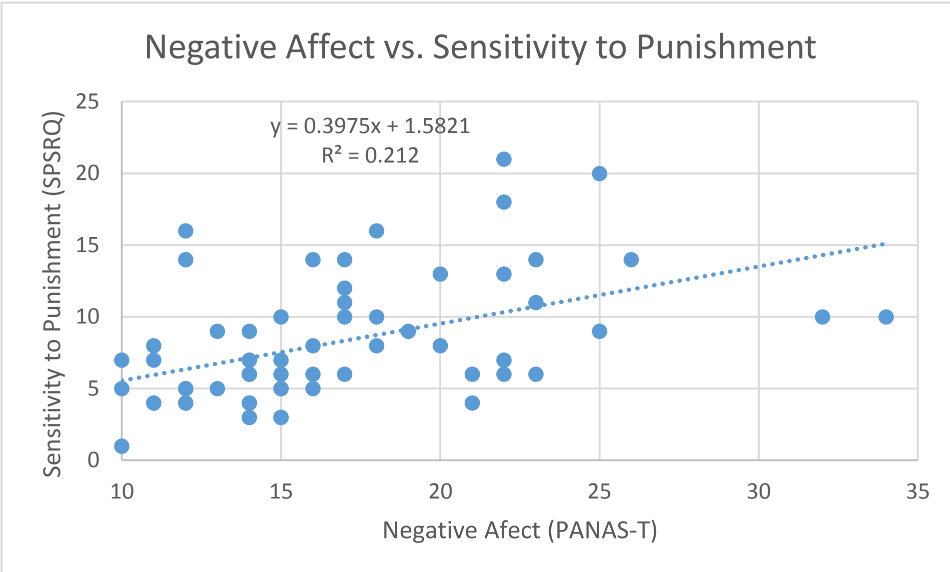

Figure 4. Negative Affect (PANAS-T) vs. Sensitivity to Punishment (SPSRQ)

As mentioned previously, the NDSS is designed to assess five core dimensions of tobacco dependence, along with the overall level of nicotine dependence (Shiffman, Waters, & Hickcox, 2004). There was a trend towards a positive correlation between two of those components - stereotypy and continuity, $r(61) = 0.22$, $p = 0.09$; see Figure 5.

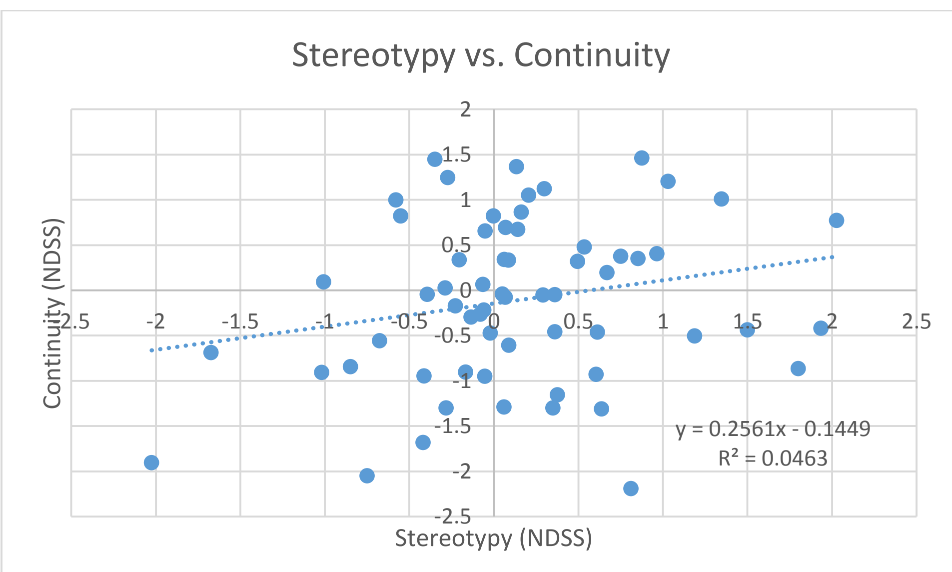

Figure 5. Stereotypy (NDSS) vs. Continuity (NDSS)

As mentioned previously, the BIS-11 is designed to measure individual differences in personality-related and behavioral facets of impulsivity (Patton, Stanford, & Barratt, 1995). Among these facets, motor impulsiveness and nonplanning impulsiveness were positively correlated, $r(61) = 0.42$, $p < 0.001$; see Figure 6.

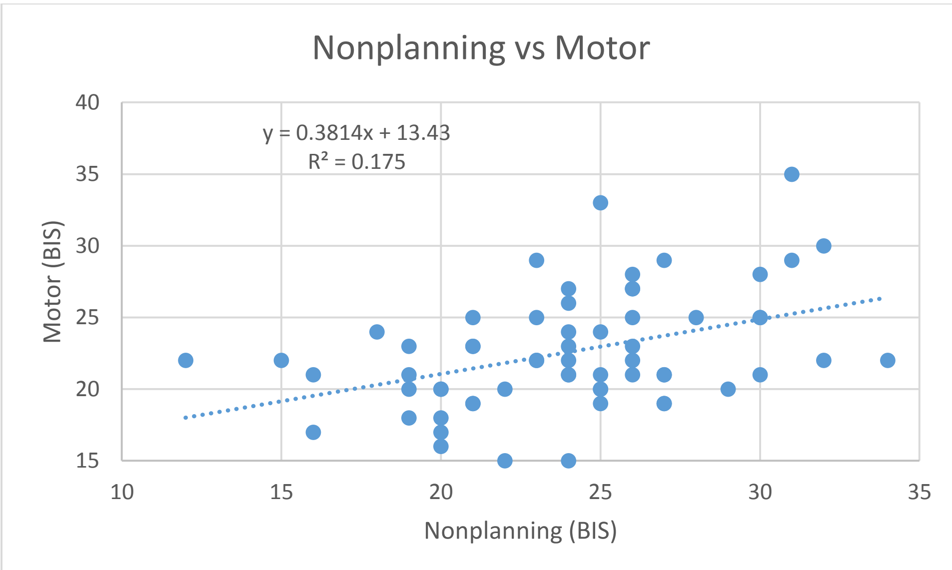

Figure 6. Nonplanning (BIS) vs. Motor (BIS)

As indicated in the figure shown below, there was a positive correlation between sensitivity to reward and motor impulsivity, $r(59) = 0.50$, $p < 0.001$; see Figure 7.

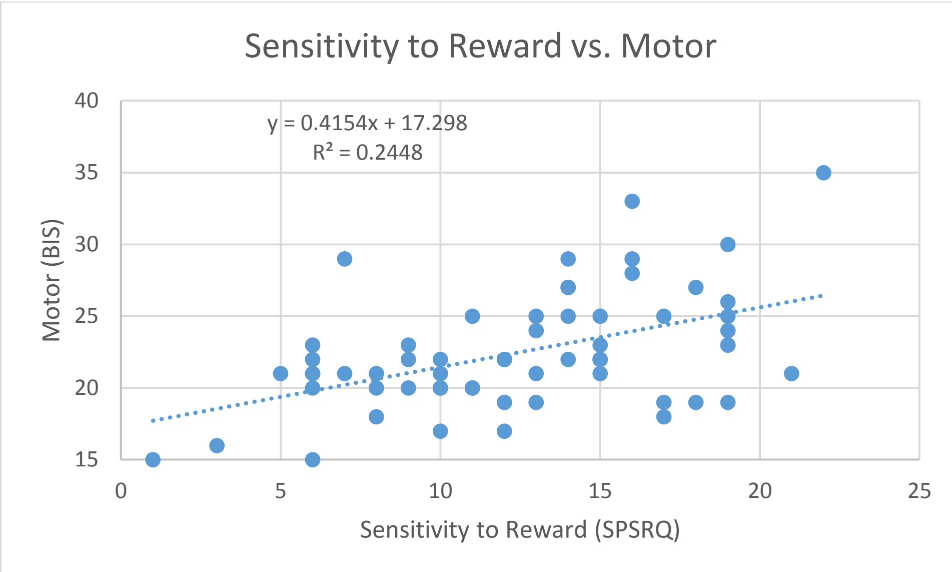

Figure 7. Sensitivity to Reward (SPSRQ) vs. Motor (BIS)

Finally, as displayed in the figure below, there was a trend towards a negative correlation between sensitivity to punishment and motor impulsiveness, $r(59) = -0.21$, $p = 0.12$; see Figure 8.

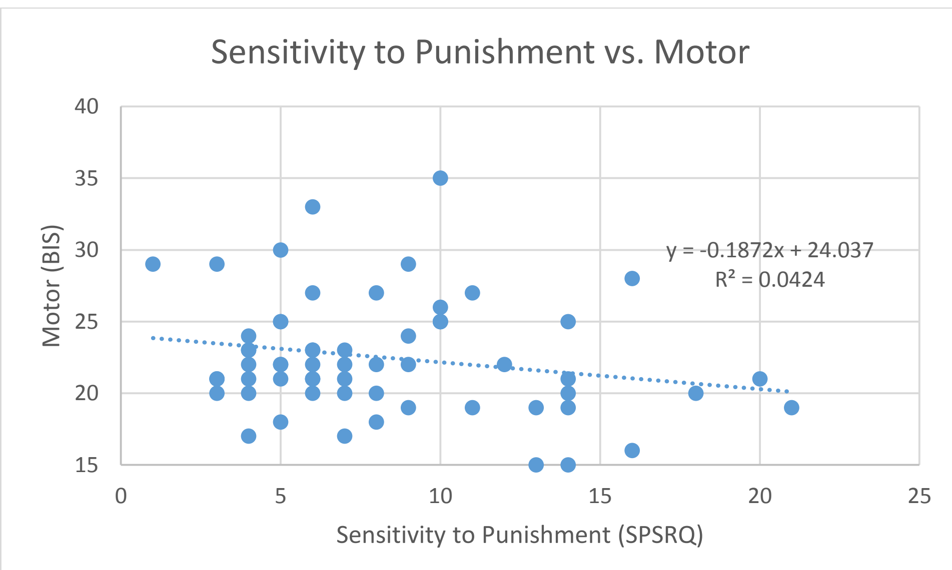

Figure 8. Sensitivity to Punishment (SPSRQ) vs. Motor (BIS)

Discussion

The goal of this study was to investigate the associations between trait impulsivity, trait sensitivity to reward, trait and state affective state, and core dimensions of nicotine dependence in individuals who smoke cigarettes. Our results indicate that there is a moderate correlation strength involved between a smoker's sensitivity to rewards (as assessed using the SPSRQ) and trait positive affect (as assessed using the PANAS-T); a similar pattern was observed for the relationship between smoker's sensitivity to punishment (as assessed using the SPSRQ) and trait negative affect (as assessed using the PANAS-T). These results suggest that smokers who have a greater tendency to be attracted to rewards also tend to experience higher levels of positive affect, while those who have a greater tendency to be motivated to avoid punishment also tend to experience higher levels of negative affect.

In terms of smoking, this may relate to the desire to seek rewards, such as smoking, by some smokers in order to obtain a more positive emotion. Indeed, Martin-Soelch et al. (2001) argued that reward processing and positive emotions are intertwined, such that obtaining a reward is associated with pleasant feelings and an increase in the motivation to strive towards that reward in a goal-object manner. In contrast, abstaining from smoking, such as during a quit attempt, can be viewed as a punishment to smokers, which may subsequently elicit a more negative emotional state. Some smokers (those who are particularly sensitive to punishment and prone to experiencing negative affect) may be driven to smoke in part to help avoid punishment and alleviate negative emotions.

Related to this point, previous research suggests that there is a connection between negative emotions and poor self-control. Specifically, when experiencing negative affect, people are more inclined to select a reward that leads to immediate gratification, at the expense of larger alternative rewards that require delaying gratification (Slessareva & Muraven, 2004). Carver & White have found that individuals with a higher sensitivity to punishment tend to have less self-control than individuals with a lower sensitivity to punishment (Carver & White, 1994). In the current study, individuals with a high sensitivity to punishment were more likely to experience negative emotions. Therefore, a smoker's impulsive decision to smoke a cigarette in order to avoid the negative emotions involved regarding to abstaining, such as cravings and withdrawals, may lead to the fact that smokers overall exhibit lower levels of self-control, especially when experiencing negative emotions and being sensitive to punishment when not smoking. Therefore, smokers with high punishment sensitivity and/or high trait negative affect may be more likely to act impulsively and exhibit the motivation to smoke a cigarette than those with high reward sensitivity and/or high trait positive affect.

However, when comparing scores on the SPSRQ to scores on the PANAS-S, the correlation strengths were weaker, with only the correlation between negative affect and sensitivity to punishment being statistically significant. Therefore, the current state of the participant may have been affected by nicotine withdrawal, because participants completed the PANAS-S questionnaire in the second session of the study following 12 hours of abstinence from smoking. The effects that the participants felt from abstaining from smoking may have led to an increase in experiencing negative emotions and a decrease in positive emotions, as observed when comparing mean scores on the PANAS-S and PANAS-T. Taken together, the current results suggest that sensitivity to rewards and punishments may be more strongly linked to trait affect than to state affect following nicotine withdrawal in smokers.

Previous research has indicated that those who are more vulnerable to negative affective states have a subsequently higher likelihood of relapse when attempting to quit smoking

(Piasecki, Kenford, & Smith, et al., 1997). In turn, individuals who exhibit more emotional sensitivity are also more likely to experience more severe symptoms of acute nicotine withdrawal (Zvolensky, Feldner, & Leen-Feldner, 2005). As a result, when people are in a negative state or have a history of negative states such as depression, they are susceptible to experiencing more severe symptoms following nicotine withdrawal and to relapsing during a quit attempt (Covey, Glassman, & Stetner, 1990). These negative emotional states may predispose individuals to relapse because smoking provides an outlet for them to experience more positive emotions and escape from the negative aspects of withdrawal, such as anxiety and distress. Based on these previous research findings, it would seem to emphasize the point that the negative aspects associated with cravings and withdrawals, which make smokers increasingly uncomfortable overall as time progresses, would be a driving factor in determining how they would react when faced with the choice between continuing to endure negative emotions during an abstinence attempt and reducing these aversive symptoms by smoking a cigarette.

Interestingly, heavy smokers who could not remain abstinent for over a week exhibited higher levels of cognitive-affective reactivity (e.g., greater levels of anxiety) compared to those who were able to abstain from smoking for over a week, but the perception of physiological responses associated with hyperarousal (i.e., the increase in heart rate and respiration produced by deep knee bends) did not differ between groups (Zvolensky, Feldner, & Eifert et. al, 2001). Zvolensky et al. suggested that individual responses to interoceptive sensations influence the emotional response patterns that are displayed during acute nicotine abstinence (Zvolensky, Feldner, & Eifert et. al, 2001). Therefore, affective reactivity based on withdrawal and cravings, for example, may have a greater influence on smokers that physiological sensations associated with abstinence per se.

The current results indicate that the emotions and perceptions of smokers may serve as an indicator of how they will behave in regards to smoking. Smokers who are more likely to experience trait positive affect are also likely to exhibit a higher sensitivity towards rewards. In contrast, smokers who are more likely to experience trait negative affect are also likely to exhibit a higher sensitivity towards punishment. However, based on the results indicating that our participants generally exhibit higher levels of positive affect compared to negative affect and higher sensitivity to rewards compared to punishment, they are generally in a more positive mood and exhibit greater response towards reward as opposed to the opposite. Therefore, smoking a cigarette may perhaps be driven to a greater extent by the positive aspects of smoking, such as the hedonic attributes and pleasure associated with a smoking opportunity, as opposed to the negative consequences associated with nicotine abstinence. Future research exploring this possibility would be useful.

Results from the current study also indicated that different dimensions of nicotine dependence are related to one another. The NDSS measures five different aspects of nicotine dependence (Shiffman, Waters, & Hickcox, 2004). We observed a positive correlation between the continuity and stereotypy facets of dependence, suggesting that smokers who develop a consistent pattern of smoking cigarettes also tend to develop smoking behavior that is characterized by rigidity (i.e., it is not heavily influenced by contextual/environmental factors). As a result, it can be progressively more difficult for smokers to quit due to the reduced sensitivity to affective and motivational cues (Wilson, Delgado, McKee, et al., 2014). The results show a relatively weak trend-level correlation that was not statistically significant, but one that may be worth exploring in relation to the development and treatment of smoking habits in future research.

Since these two aspects of the NDSS capture smoking behavior that is based on nicotine dependence in terms of smoking patterns, it is definitely an aspect to consider regarding developing therapies to quit smoking. At a broad level, more research on these factors may promote a greater understanding of the progression of addiction behavior and lead to the development of more effective treatment plans for smokers who wish to quit, but have been previously unsuccessful. Previous research suggests that it is more difficult to control the behavioral risk factors that predict chronic disease than it is to modify the risk factors for infectious disease (Ebert, 1978). Therefore, intervention aimed at risk factors linked to behavior requires careful attention not only to the intervention process, but to the processes involved in the targeted risk behavior (Leventhal, 1973). These points emphasize that the behavior of smokers contributes greatly to the overall effects observed in regards to addiction and nicotine dependence. Leventhal points out that failed attempts to change a particular behavior are due to not recognizing the combination of many factors that are involved in the observed attitudinal-behavior system (Leventhal, 1973). Simply telling an individual that smoking can lead to cancer development is not enough for the behavior to change because he or she may fail to perceive or believe it. However, understanding the multiple aspects involved in the behavior of smoking, such as doing it as a mechanism to reduce anxiety or to increase stimulation, and tackling each one individually in therapies has the potential to lead to significant treatment gains. Such a multifaceted approach may help promote behavioral change for smokers by targeting factors surrounding the behavior and attitude itself.

The correlation between stereotypy and continuity may help to explain how nicotine dependence develops over time. Reinforcing a particular behavior such as smoking can cause conditioning, which can promote the consistent and rigid smoking patterns. A study conducted by Shahan, Bickel, & Madden et al. (1999), found that smokers exhibited similar levels of reinforcing efficacy when they were given both cigarettes containing nicotine and "denicotinized" cigarettes (i.e., a cigarette that is devoid of active amounts of nicotine). However, there was a preference for the cigarettes containing nicotine when a choice was given. Additionally, the action of smoking a cigarette provides a link between the effects to nicotine and the visual stimulus that is provided through cigarettes. As a result, conditioning such as being presented a characteristic stimulus related to smoking (e.g., the sight of a cigarette) can contribute to the reinforcing properties associated with smoking. Since a moderately heavy smoker repeats the act of smoking thousands of time throughout one year, it leads to a strong conditioning association between the sensory aspects of smoking and the pharmacological effects of nicotine (Rose and Levin, 1991).

As previously mentioned, research has found relations between impulsivity and smoking behaviors. Smokers typically exhibit higher levels of impulsivity compared to nonsmokers (Bickel, Odum, & Madden, 1999). Furthermore, smoking is associated with elevated motor impulsivity (Mitchell, 1999) and impaired inhibitory control (Spinella, 2002). These three studies further emphasize that poor decision making through impulsive choice might be a reliable predictor of relapse behavior, while elevated motor impulsivity may be a risk factor in initiating smoking behavior. Additionally, it has been suggested that the association between impulsive behavior and drug addiction (including nicotine dependence) may relate in part to executive functioning deficits linked to abnormalities in the frontal cortex of the brain (Jentsch & Taylor, 1999). Consistent with this view, a recent preclinical study observed strong associations between different sub-dimensions of impulsivity and nicotine self-administration in rats (Diergaarde, Pattij, & Poortvilet, et al. 2008). Specifically, greater impulsive action (assessed using a five-choice serial reaction time task) predicted heightened motivation to initiate and maintain nicotine self-administration. In addition, greater impulsive action was associated with decreased ability during abstinence to inhibit nicotine seeking behavior and an increased vulnerability to relapse when re-exposed to nicotine cues following extinction (Diergaarde, Pattij, & Poortvilet, et al. 2008).

In this study, the BIS-11 (Patton, Stanford, & Barratt, 1995) was used to examine the relationships among distinct facets of impulsivity (e.g., attention, motor, and nonplanning impulsiveness) and smoking behavior. At a broad level, impulsivity and self-control can be considered antagonistic aspects of decision making in which greater impulsivity reflects a preference for smaller/immediate rewards over larger/delayed rewards, whereas greater self-control reflects the opposite behavior (Kalenscher, Ohmann, & Güntürkün, et al., 2006). Kalenscher et al. further emphasize that self-controlled choices may also require additional and more complex cognitive control mechanisms (Kalenscher, Ohmann, & Güntürkün, et al., 2006). The current results highlight two specific aspects of impulsivity that may tend to covary in smokers, which may have implications for understanding the maladaptive decision making that is exhibited by this population.

A moderate positive correlation was observed between the motor and nonplanning aspects of impulsiveness. These results aid in developing a more comprehensive understanding of precisely how impulsivity is related to smoking behavior. That is, dividing impulsivity into its components based on the BIS-11 provides a more nuanced picture regarding the personality characteristics that may contribute to the impulsive decision to begin or resume smoking.

Based on previous research indicating that smokers tend to act impulsively in order to obtain small and short-term rewards (Solnick, Kannenberg, & Eckerman, et al., 1980), BIS motor and SPSRQ results were compared in order to observe if smokers who tend to act on impulse also tend to exhibit higher sensitivity to reward and/or punishment. There was a significant positive correlation between motor impulsiveness and sensitivity to reward and a trend towards a negative correlation between motor impulsiveness and sensitivity to punishment. Therefore, smokers may act with a greater intention towards obtaining the reward of smoking a cigarette compared to refraining from experiencing punishment through withdrawal symptoms. Smoking a cigarette may be thought of as a form of short-term reward in which the nicotine obtained from smoking affects individuals quickly through rapid absorption in pulmonary circulation, thereby causing peak blood levels to occur quickly (Benowitz, Porchet, & Sheiner, et al., 1988). For certain individuals, the acutely rewarding consequences of smoking may promote smokers to act impulsively towards obtaining these short-term rewards instead of exhibiting self-control for long-term rewards, such as cessation, due to their heightened sensitivity to rewards in general.

One explanation for this preference may be due to smokers choosing a sure outcome (smoking a cigarette) as opposed to a probabilistic outcome (quitting smoking) (Kahneman & Tversky, 1979). The uncertainty of the potential long-term rewards associated with quitting smoking may discourage smokers from attempting to do so. In addition, the duration of time required to obtain a reward may be another factor involved in determining why smokers prefer to obtain the short-term reward such as smoking over a long-term rewards such as those that occur as a result of quitting (Wittman & Paulus, 2007). Wittman and Paulus further emphasize that individuals who tend to act more impulsively may have a different perception of time that influences their decision to pursue immediate rewards (i.e., they may perceive the delay to receiveing a long-term reward as “too long” and perhaps burdensome to obtain).

In conclusion, there are myriad factors that influence cigarette use, including nicotine dependence, impulsivity, emotional state, and sensitivity to reinforcement. The goal of the current study was to help shed light on the way that these variables relate to one another. Clearly, the current study should be considered an initial preliminary step towards this goal. The relationships between all of these aspects should be further researched in order to more clearly establish how they relate to individual differences in smoking behavior. Although limited in many important ways, results from the current study point towards several useful avenues for future work (e.g., exploring the extent to which sensitivity to rewards influences the effectiveness of various smoking treatments, such as those that involve the delivery of incentives for abstinence), which can be potentially explored using similar methods (e.g., questionnaires). In addition, given the complexity of the various dimensions that contribute to smoking behavior, such as the behavioral and neurobiological components, examining such questions using a variety of methods will likely be necessary. Studies using functional brain imaging methods (e.g., fMRI) have shown promise in determining how smokers perceive drug-related and nondrug (Wilson, Smyth, & MacLean, 2013). Future directions may involve incorporating neuroimaging and behavioral methods to provide deeper insight into the psychological and neurobiological mechanisms that underlie smoking, as well as how these mechanisms vary across individuals.

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Academic Vita

STEPHEN A. LAVANIER

EDUCATION

Baccalaureate Degree in Biochemistry and Molecular Biology with Honors in Psychology
Aug 2010 – Dec 2013, Jan 2015 - May 2015

Minor in Chemistry and Psychology

The Pennsylvania State University - University Park, PA

Schreyer Honors College

EXPERIENCE

Psychology Research Assistant Jan 2013 – May 2013, Aug 2013 - Dec 2013, Jan 2015 – May 2015

Smoking Research Laboratory - Department of Psychology

The Pennsylvania State University - University Park, PA

- Evaluated smoking reward perceptions by exploring the associations among impulsivity, sensitivity to reward, affective state, and nicotine dependence for thesis.
- Conducted experiments with college-aged participants regarding risk-taking behavior.

Endoscopy Technician Jul 2012 – Aug 2012, May 2013 – Aug 2013, Dec 2013 – Jan 2015

Frederick Endoscopy Center - Frederick, MD

- Assisted with various gastroenterology procedures by performing biopsies on polyps or areas of interest and preparing patients for procedures
- Placed postpolypectomy endoclips and tattooed areas with large polyps or many polyps.
- Filed medical documents for practice's transition to electronic medical records.

Stem Cell Research Intern Dec 2010 – Jan 2011

Mouse Cancer Genetics Program

The National Cancer Institute, Frederick, MD

- Examined protein expression profiles of neurotrophin receptors in the pluripotent state of H9 human embryonic stem cells.
- Directed differentiation of embryonic stem cells to motor neurons and maintained these cells.

Leukemia Research Intern Jun 2009 - Aug 2010, May 2012 – Jul 2012

Retroviral Molecular Pathogenesis Section of the Laboratory of Cancer Prevention

The National Cancer Institute, Frederick, MD

- Investigated the mechanisms of action of JS-K, by performing parallel experiments with CDNB which has an aromatic ring analogous to that of JS-K.
- Obtained results that promote understanding of the biological mechanisms of action of JS-K, which is required for clinical trials.
- Proved involvement of two, instead of the originally designed one, components of JS-K activity.

PUBLICATIONS

Leukemia Research **Volume 38, Issue 3, March 2014, Pages 377–382**

"Mechanism of action for the cytotoxic effects of the nitric oxide prodrug JS-K in murine erythroleukemia cells"

Monika Z. Kaczmarek, Ryan J. Holland, Stephen A. Lavanier, Jami A. Troxler, Valentyna I. Fesenkova, Charlotte A. Hanson, Joan L. Cmarik, Joseph E. Saavedra, Larry K. Keefer, Sandra K. Ruscetti

POSTER PRESENTATIONS

National Cancer Institute Student Exhibition	**Aug 2010**
Intel International Science and Engineering Fair	**May 2010**
National Cancer Institute Spring Research Festival	**May 2010**
American Association for Cancer Research	**Apr 2010**
Frederick County Science and Engineering Fair	**Mar 2010**
Center for Cancer Research – Fellows and Young Investigators Colloquium	**Mar 2010**
National Institutes of Health Research Festival	**Oct 2009**

AWARDS

Kevin Daniel Gilmore Memorial Scholarship	**Aug 2013 – Dec 2013, Jan 2015 – May 2015**
Dean's List	**Aug 2010 – Dec 2013, Jan 2015 – May 2015**
Shapiro Family Scholarship	**Aug 2010 – Dec 2013, Jan 2015 – May 2015**
3rd Place in Cellular and Molecular Biology Category in Intel International Science and Engineering Fair	**May 2010**
National Cancer Institute Spring Research Festival Student Category Winner	**May 2010**
Grand Prize Winner in Frederick County Science and Engineering Fair	**Mar 2010**
Maryland Distinguished Scholar Honorable Mention	**Sep 2009**
National Honor Society	**Aug 2008 – May 2010**

Leadership

Resident Assistant **Aug 2012 – May 2013, Aug 2013 – Dec 2013**

- Created community builders for residents to promote interaction and unity
- Enforced residence life policies to promote a safe environment for residents

Co-Facilitator **Jan 2013 – May 2013, Aug 2013 – Dec 2013**

- Led discussions and lessons about residence life to emphasize the Resident Assistant (RA) roles and responsibilities involved to prospective students wanting to become RA's
- Graded assignments and provided feedback to students about their progress in class

Penn State LeaderShape **May 2013**

- Participated in a weeklong leadership retreat learning how to be a more effective leader

PNC Leadership Assessment Center **Nov 2012**

- Participated in leadership exercises to evaluate various leadership aspects and potential