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Tobacco demand, delay discounting, and smoking topography among smokers with and without psychopathology

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ABSTRACT

Introduction: Tobacco demand (i.e., relative value attributed to a given reinforcer) and delay discounting (i.e., relative preference for smaller immediate rewards over larger delayed rewards) are two behavioral economic processes that are linked to the progression of problematic substance use. These processes have not been studied among those with psychopathology, a vulnerable group of smokers. The current study examined differences in tobacco demand and delay discounting, and their association with smoking topography among smokers with (n = 43) and without (n = 64) past-year psychopathology.
Method: Adult daily smokers (n = 107, M_{age} = 43.5; *SD* = 9.7) participated in a study on "smoking behavior." Past-year psychological disorders were assessed via a clinician-administered diagnostic assessment. All subjects participated in an *ad libitum* smoking trial and then completed an assessment of delay discounting (Monetary Choice Questionnaire) and tobacco demand (Cigarette Purchase Task) approximately 45–60 min post-smoking.
Results: Smokers with psychopathology, compared to those without, had significantly higher demand intensity and maximum expenditure on tobacco (O_{max}), but did not differ on other demand indices or delay discounting. Smokers with psychopathology had shorter average inter-puff intervals and shorter time to cigarette completion than smokers without psychopathology. Tobacco demand and delay discounting measures were significantly intercorrelated among smokers with psychopathology, but not those without. Both behavioral economic measures were associated with specific aspects of smoking topography in smokers with psychopathology.
Discussion: The association between tobacco demand and delay discounting is evident among smokers with psychopathology and both measures were most consistently related to smoking behavior.

1. Introduction

Despite reductions in the prevalence in smoking over the past fifty years (United States Department of Health and Human Services, 2014), approximately 36.5 million Americans still smoke which is about 15.1% of the US population (Centers for Disease Control and Prevention, 2016). However, the prevalence of smoking among individuals with a psychological disorder is significantly higher (36.1%) than the general population (Centers for Disease Control and Prevention, 2013; Lasser et al., 2000; McClave et al., 2010) and has remained relatively stable at this rate over recent years (Centers for Disease Control and Prevention, 2013). Increased scholarly efforts have focused on understanding

factors that contribute to the maintenance of smoking and stagnated cessation rates among this vulnerable sub-set of smokers.

One way to study smoking behavior among those with psychopathology is through a behavioral economics framework. Behavioral economics integrates principles from psychology and economics in an effort to analyze key processes involved in decision-making (Camerer, 1999). This framework has been applied to understand substance use behaviors through the "reinforcer pathology" model (Bickel et al., 2014, 2011). Reinforcer pathology comprises the dual effects of two fundamental processes related to the progression of problematic substance use: (a) persistently elevated value attributed to a given reinforcer and/or (b) the excessive preference for obtaining or consuming

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a given reinforcer immediately despite long-term consequences (Bickel et al., 2014, 2011). This theoretical model posits that individuals with substance use disorders, dependence, or problematic use may regularly attribute high value to a preferred substance while also exhibiting a desire to obtain and use it instantaneously. Two behavioral economic indices allow for objective evaluation of reinforcer pathology: substance demand and delay discounting (DD).

Substance demand pertains to the perceived value of a given substance (Hursh et al., 2005). Cigarette purchase tasks (CPT) are one way to assess demand for tobacco via examination of hypothetical tobacco consumption at a range of prices (MacKillop et al., 2008). These tasks capture related, yet distinct, aspects of tobacco demand including: intensity (amount of tobacco consumed at zero cost), P_{max} (price at maximum expenditure for tobacco), O_{max} (peak expenditure for tobacco), breakpoint (cost whereby tobacco consumption is suppressed to zero), and elasticity of demand (the degree to which consumption decreases with increasing price). Tobacco demand indices appear to be moderately correlated with tobacco dependence and smoking frequency (MacKillop et al., 2008; Murphy et al., 2011), increase in response to acute nicotine deprivation and cue-induced craving (MacKillop et al., 2012), and are associated with lower motivation for smoking cessation (Murphy et al., 2011). Limited work has examined the impact of psychopathology on tobacco demand. Initial studies indicate that elevated depression symptoms and emotional disorders are associated with higher tobacco demand indices, especially under stress (Dahne et al., 2017a) or nicotine-deprived states (Farris et al., 2017). Other work has found that smokers with schizophrenia have higher intensity of demand, relative to healthy controls, when completing a hypothetical CPT under satiated states (MacKillop and Tidey, 2011). Thus, available data, albeit limited, indicates that smokers with various forms of psychopathology may have volumetric differences (e.g., heavy use) in demand.

DD refers to the propensity to discount future rewards over immediate rewards (MacKillop et al., 2011). For example, when asked to choose between a larger, delayed amount of money (e.g., $100 in 6 months) and an immediate smaller amount of money (e.g., $75 today), the rate at which a participant switches from preferring the smaller-sooner reward to a larger-later reward can be plotted as a function of delay (i.e., discount function), with *steeper* DD reflecting greater impulsive behavior. The undervaluation of future rewards (steeper DD) is a key characteristic of problematic health behaviors (Amlung et al., 2017, 2016), including cigarette smoking (Amlung et al., 2017). Additionally, steeper DD has been observed in various psychological disorders, including those characterized by impulsivity (hypomania/mania, attention deficit-hyperactivity disorder), disorders of cognitive or executive dysfunction (e.g., schizophrenia), and disorders involving future-focused uncertainty/fear (e.g., posttraumatic stress disorder, anxiety disorders, borderline personality disorder; Cáceda et al., 2014; Story et al., 2016). Despite the clear documented link between psychological disorders and DD, limited work has examined the nature of DD among smokers with psychological disorders. Self-reported depression has been found to be related to steeper DD in treatment-seeking pregnant female smokers (Yoon et al., 2007) and adolescent smokers (Imhoff et al., 2014), but not in all cases (Weidberg et al., 2015a). In smokers with schizophrenia, DD was not significantly different from healthy controls (MacKillop and Tidey, 2011), although discounting rate appears to be steeper among current and former smokers with schizophrenia relative to never smokers with schizophrenia (Wing et al., 2012). Thus, some data indicate that psychopathology influences DD in smokers.

In the current study, we examined the nature of tobacco demand and DD in smokers with various forms of psychopathology (internalizing and externalizing disorders) versus those without. Despite heterogeneity in disorders, common underlying factors (e.g., high levels of emotional distress, poor coping with negative distress states, difficulties with emotion regulation) promote and maintain both internalizing and externalizing disorders (e.g., substance use, eating disorders, anxiety disorders, mood disorders; Mennin et al., 2007; Tice et al., 2001). Thus, we aimed to explore these associations among smokers with various forms of psychopathology. Specifically, we examined differences in demand and DD among smokers with and without past-year psychopathology, following approximately 60 min of smoking deprivation. This assessment window allowed for the onset of tobacco craving, which can occur within 30 min of not smoking (Hendricks et al., 2006). Based on the existing literature, it was hypothesized that smokers with psychopathology would exhibit elevated demand and steeper DD. Additionally, we explored the associations between demand and DD as a function of psychopathology status and their association with smoking topography, a behavioral index of smoking reinforcement.

2. Material and methods

2.1. Participants

Non-treatment seeking adult daily smokers were recruited for an experimental study on "smoking behavior" (Farris and Zvolensky, 2016). Community-recruited individuals who were between 18 and 65 years of age, reported smoking 10 or more cigarettes per day for at least one year, and smoked within the first 30 min of waking in the morning, were invited for a baseline assessment to determine eligibility for the experimental study (Farris and Zvolensky, 2016). Participants were excluded from participation during an initial telephone screen if they reported frequent drinking (≥ 9 standard drinks/week), illicit drug use (≥ 3 days/week), unstable medical conditions, or current psychotic symptoms. The current study is a secondary analysis of data from participants who completed the baseline assessment (n = 126), regardless of eligibility for the experimental phase of the study.

2.2. Measures

2.2.1. Demographic characteristics

Demographic characteristics were assessed via self-report. The *Financial Strain Questionnaire* (Pearlin et al., 1981), which was adapted from an economic strain measure, was used as a proxy for income. The FSQ, is an 8-item self-reported measure that assesses perceived difficulty affording clothes, leisure activities, car, furniture, and other necessities (i.e., medical care, housing). Items that are rated on a scale from 1 to 3 (e.g., "I have enough money", "I have somewhat enough money", "I don't have enough money"). Monetary status at the end of the month is also assessed using a similar scaling (1 = *some money left over*, 3 = *no money left over*). Items are summed to derive a total financial strain index, with higher scores indicating greater strain (possible range 8–24).

2.2.2. Smoking history

The *Smoking History Questionnaire* (SHQ; Brown et al., 2002), a 30-item self-report measure, was used to gather information about smoking history to establish pattern of cigarette use per eligibility criteria (e.g., daily use). A *Carbon Monoxide (CO) Analysis,* using the Vitalograph Breath Co carbon monoxide monitor, was conducted to measure the amount of CO (in parts per million [ppm]) in an expired breath sample. The *Timeline Follow-Back Interview* (Brown et al., 1998) is a calendar-based assessment of substance use, which was used to document frequency, quantity, and patterns of tobacco use in the past 30 days. The *Fagerström Test for Cigarette Dependence* (Fagerström, 2012), a 6-item scale that assesses gradations in cigarette dependence, was used to assess the level of physiological dependence on tobacco (range 0–10, with higher scores reflecting higher levels of dependence). The FTCD has adequate internal consistency and is associated with biochemical indicators of smoking (Heatherton et al., 1991; Pomerleau et al., 1994)