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Predictors of delay discounting among smokers: Education level and a Utility Measure of Cigarette Reinforcement Efficacy are better predictors than demographics, smoking characteristics, executive functioning, impulsivity, or time perception

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HIGHLIGHTS

- Delay discounting and other characteristics were measured in ninety-four smokers.
- Education level negatively correlated with discounting.
- Utility Measure of Cigarette Reinforcement positively correlated with discounting.
- Results correspond with several dual-system neuroeconomic models of decision-making.

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ABSTRACT

Ninety-four smokers completed the delay discounting procedure for either hypothetical amounts of money, $10 (money) and $1000 (money) or hypothetical amounts of cigarettes ($10 and $1000 worth of cigarettes). We investigated how variables previously found to be related to rates of delay discounting accounted for the observed results. These variables included the following: demographic information, smoking characteristics, executive function abilities, impulsivity, time perception, and the Utility Measure of Cigarette Reinforcing Efficacy (UMCE). Education level and UMCE were each significantly correlated with 3 out of 4 of the discounting measures. Moreover, the largest effect sizes observed were between these two measures and the four discounting measures. All potential discounting predictors were also investigated using step-wise linear regression with Bayesian Information Criterion (BIC) analysis — these BIC models revealed that education level and UMCE accounted for large portions of the variance. We conclude that education level and UMCE were the most consistent predictors of discounting. This data is discussed within the framework of a widely accepted neuroeconomic model that suggests that two brain systems separately assess two separate facets of decision-making, and the interplay between these two systems determines self-control in smokers. We hypothesize that education level and UMCE may serve as surrogate measures of the functionality of these two systems and that discounting may be a sentinel measure of self-control.

1. Introduction

The subjective value of a reward is generally diminished when its delivery is delayed (Chung & Herrnstein, 1967; Rachlin & Green, 1972). Individuals suffering from addiction are inordinately affected by delays to reinforcement (Bickel, Koffarnus, Moody, & Wilson, 2013). This effect can be quantified with delay discounting, a procedure that asks an individual to decide between receiving smaller rewards sooner or larger rewards later (Loewenstein & Prelec, 1992; Raineri & Rachlin, 1993). The degree to which an individual subjectively devalues a reward per unit of time until its receipt can be described by a variety of accepted discounting functions (Mazur, 1987; Myerson & Green, 1995; Myerson, Green, & Warusawitharana, 2001; Yi, Landes, & Bickel, 2009, see MacKillop et al., 2011 for a review). Delay discounting has been

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used to further the understanding of substance abuse as this behavior can be conceptualized as preference for the smaller, more immediate rewards of drug use compared to the larger (but delayed) rewards of abstaining (Bechara, 2005; Bickel, Kowal, & Gatchalian, 2006; Bickel & Yi, 2008; Bickel, Yi, Mueller, Jones, & Christensen, 2010).

1.1. The Competing Neurobehavioral Decision Systems model of substance abuse

Several dual decision models have been proposed to account for addiction (Bechara, 2005; Jentsch & Taylor, 1999), and one referred to as the Competing Neurobehavioral Decision Systems (CNDS) model of substance abuse describes the neuronal components of discounting and the disruption of these systems which co-occurs with addiction (Bickel, Jarmolowicz, Mueller, & Gatchalian, 2011; Bickel et al., 2007). This model posits that one's rate of discounting is derived from the interplay between the frontal cortex and the limbic system. As evidence of this, activity in the frontal cortex has been shown to correlate with an individual's assessment and selection of delayed rewards, whereas limbic system activity is related to assessment and selection of immediate rewards (McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007; McClure, Laibson, Loewenstein, & Cohen, 2004). Individuals who abuse illicit substances, a population known to have delay discounting deficits (Bickel et al., 2013), tend to have a corresponding prevalence of dysfunction in these two brain areas. Compared to non-addicted individuals, the pre-frontal cortex of substance dependent individuals has been shown to be smaller in volume on average (Fein, Di Sclafani, & Meyerhoff, 2002), and display neuronal hyperactivity, but hypoactivity during withdrawal (Goldstein & Volkow, 2002). Likewise, chronic drug users tend to show greater dopaminergic activity (Salokangas et al., 2000) and abnormal connectivity in neuronal pathways that are important for reward-based learning (Belin, Jonkman, Dickinson, Robbins, & Everitt, 2009). Finally, greater connectivity and irregular resting state activity within both of these brain regions has been observed in chronic heroin users (Ma et al., 2010).

1.2. General addiction and discounting

In clinical and sub-clinical domains, researchers have examined the effects of trait and state variables on discounting rates for various commodities both across and within individuals (Odum, 2011a,b). Studies suggest that persons dependent upon drugs discount the value of delayed rewards more than healthy controls. This result has been observed in individuals addicted to heroin (Kirby & Petry, 2004; Kirby, Petry, & Bickel, 1999; Madden, Petry, Badger, & Bickel, 1997; Vassileva, Georgiev, Martin, Gonzalez, & Segala, 2011), cocaine (Bickel, Landes, et al., 2011; Camchong et al., 2011; Coffey, Gudleski, Saladin, & Brady, 2003; Heil, Johnson, Higgins, & Bickel, 2006; Kirby & Petry, 2004; Moeller et al., 2002; Petry & Casarella, 1999), and in alcoholics (Bjork, Hommer, Grant, & Danube, 2004; Bobova, Finn, Rickert, & Lucas, 2009; Finn & Hall, 2004; Mitchell, Fields, D'Esposito, & Boettiger, 2005; Petry, 2001; Vuchinich & Simpson, 1998). Further, when those with an addiction make decisions about the drug they are dependent on, the observed rate of discounting is greater than discounting rates for money. Again, this is true for individuals who are addicted to cocaine (Coffey et al., 2003), heroin (Madden et al., 1997; Odum, Madden, Badger, & Bickel, 2000), as well as alcoholics (Petry, 2001).

1.3. Cigarette smoking and discounting

Aberrant discounting can also be seen in those who smoke cigarettes: adult smokers have higher discounting rates than healthy controls (Baker, Johnson, & Bickel, 2003; Bickel, Odum, & Madden, 1999; Bickel, Yi, Kowal, & Gatchalian, 2008; Businelle, McVay, Kendzor, & Copeland, 2010; Johnson, Bickel, & Baker, 2007; Mitchell, 1999; Odum, Madden, & Bickel, 2002; Reynolds, Leraas, Collins, & Melanko, 2009; Reynolds, Richards, Horn, & Karraker, 2004; Rezvanfard, Ekhtiari, Mokri, Djavid, & Kaviani, 2010), as do adolescent smokers (Fields, Leraas, Collins, & Reynolds, 2009; Reynolds et al., 2007). Adult smokers discount more when the commodity is cigarettes, as opposed to money (Bickel et al., 1999), and recent evidence suggesting that rates of delay discounting may predict relapse to smoking (MacKillop & Kahler, 2009; Mueller et al., 2009; Sheffer et al., 2012; Yoon et al., 2007).

The relationship between discounting rates and smoking is, however, mitigated by many factors. Age has been shown to either decrease (Green, Fry, & Myerson, 1994; Green, Myerson, Lichtman, Rosen, & Fry, 1996) or increase (Reynolds, 2004) discount rate, whereas a negative correlation between discounting and IQ was observed in de Wit, Flory, Acheson, McCloskey, and Manuck (2007). Variables specific to one's smoking habit also affect discounting. The amount one smokes tends to be positively correlated with rate of discounting (Epstein et al., 2003; Ohmura, Takahashi, & Kitamura, 2005; Reynolds, 2004; Yi et al., 2008, although see Johnson et al., 2007; Sweitzer, Donny, Dierker, Flory, & Manuck, 2008) and daily smokers tend to discount more than non-daily smokers (Epstein et al., 2003; Ohmura et al., 2005; Yi et al., 2008). Factors affecting the assessment of future rewards, specifically their temporal horizons (Jones, Landes, Yi, & Bickel, 2009) and their executive functioning ability (Bickel & Yi, 2008), have also been shown to affect discount rate in smokers.

1.4. Using the CNDS model to elucidate the multi-facetted relationship between cigarette smoking and discounting: the current study

Related to the CNDS model discussed above, education level correlates with frontal cortex activity (Springer, McIntosh, Winocur, & Grady, 2005) and has been found to be inversely related to discounting rate in smokers (Jaroni, Wright, Lerman, & Epstein, 2004) and others (Appelhans et al., 2011; Bauer & Chytilova, 2010; Jaroni et al., 2004; Kirby et al., 2002; Reimers, Maylor, Stewart, & Chater, 2009). Whereas individuals who smoke have greater dopamine activity in the basal ganglia, a component of the limbic system (Salokangas et al., 2000), and levels of dopamine in this brain region has been shown to be a major determinant of one's ability to express self-control (Montague, Hyman, & Cohen, 2004).

Given the large range of factors shown to relate to the rate of discounting in smokers the current study sought to 1) comprehensively assess previously identified variables affecting discounting in smokers, 2) determine whether these variables systematically affected discounting when the commodities and magnitudes of the rewards assessed are varied, and 3) investigate the interactions among these factors when considering discounting behavior within the framework of the CNDS model. Here for the first time we examine correlations among variables related to the rates of delay discounting for both hypothetical money and hypothetical cigarettes at either $10 or $1000 dollars and then model the subjects' discounting behavior to see which factors were selected as the best predictors. The factors included demographic information including education level, smoking characteristics, executive functioning, impulsivity, time perception and the reinforcement efficacy of nicotine.

Given that the effects of the previous factors and cigarette smoking on discounting were not originally investigated within the framework of the CNDS model and, to our knowledge, have yet to be investigated in a single comprehensive study like the one proposed here, the aims of this study were exploratory in nature, but were also informed by prior information. Given this, the failure to find relationships that have been previously identified in the literature was not assumed to be contradictory, per se, but instead to imply that other factors may explain the individual differences to a better degree in this sample.